(3)

(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) Publication number: **0 607 586 A1**

(12) EUROPEAN PATENT APPLICATION

(21) Application number: **93120410.1**

(51) Int. Cl.[5]: **F24C 7/08**, H05B 6/68

(22) Date of filing: **17.12.93**

(30) Priority: **21.12.92 JP 340041/92**
10.02.93 JP 22314/93
10.08.93 JP 198131/93
08.09.93 JP 223297/93

(43) Date of publication of application:
27.07.94 Bulletin 94/30

(84) Designated Contracting States:
DE FR GB

(71) Applicant: **MATSUSHITA ELECTRIC INDUSTRIAL CO., LTD.**
1006, Oaza Kadoma
Kadoma-shi, Osaka-fu, 571(JP)

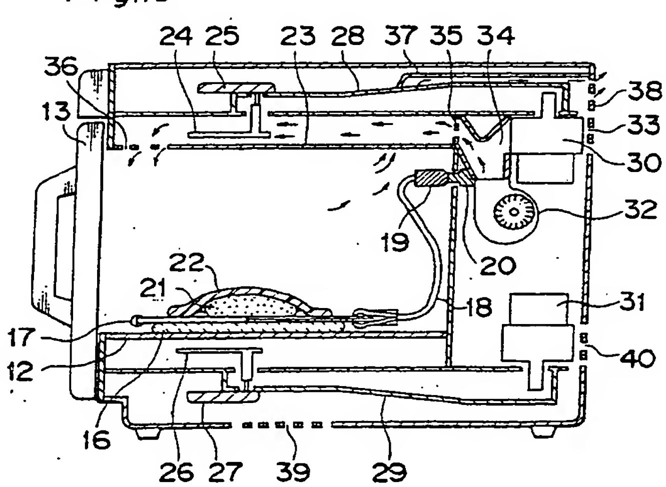
(72) Inventor: **Mori, Fumiko**
19-14 Shinpoin-cho,
Tennoji-ku
Osaka-shi, Osaka-fu 543(JP)
Inventor: **Matsushima, Haruo**
109-15 Miyado-cho
Yamatokoriyama-shi, Nara-ken 639-11(JP)

(74) Representative: **Eisenführ, Speiser & Partner**
Martinistrasse 24
D-28195 Bremen (DE)

(54) Microwave heating apparatus and method of making same.

(57) A method of heating food with microwaves, where in order to remove an uneven heating operation in food surface and interior which is a problem peculiar to the micro wave heating operation, the heat conduction of the food interior is positively used, supplying necessary minimum energies while monitoring the surface temperatures of the food, and heating food to the optimum temperature in both the surface and interior of the food. Considerable energy cost reduction is achieved and the operation environment of high temperature and much humidity can be also improved.

Fig.1b



EP 0 607 586 A1

BACKGROUND OF THE INVENTION

The present invention generally relates to a microwave heating method and apparatus for effecting a vacuum cooking operation (sous vide) with high frequency heating.

The vacuum cooking operation is to cook at a constant temperature between approximate 55 • C and approximate 95 • C vacuum packed foods by water boiling or steam oven. It has following advantages. (A) A heat conduction operation is superior because of vacuum. A uniform heating operation can be effected with a specific temperature which ensures the most delicious taste with respect to foods. (B) The permeation of seasonings is superior because of the vacuum. The seasoning can be effected with a small amount of sugar. salt, thus being desirable for the health. (C) Food is vacuum packed so that the flavor is not damaged. (D) Food is heated at low temperatures so that lines, fibers and so on are soft without becoming hardened. (E) A yield is considerably higher, because food is cooked at temperatures where water division of protein is not caused. (F) Foods can be preserved for approximately one week in cold storage so that mass supply of foods for banquets at a hotel can be conveniently provided. The vacuum cooking is invented in France and is spread quickly.

Humidity environment of a kitchen where hot water of 60 • C through 95 • C is kept is not favorable as judged easily from the humidity environment within the bath chamber of 42 • C through 43 • C in hot water temperature. The environment has a risk of being dangerous enough to cause burns. Therefore, improvements in it is strongly desired. As a fuel expenditure becomes large to maintain the hot temperatures, it is desired to be improved. These situations are much alike even in the steam ovens.

As a solution to the above problem, it is considered to use a high frequency heating apparatus such as electronic range or the like. It is extremely difficult to realize it in a conventional art, because a finish temperature width to be demanded in the vacuum cooking operation is approximately 1 • C. Although various methods are used in France, the results are said to be failures. The finish temperature width of foods in the conventional art will be approximately 20 • C in top limit.

The uniform heating method by the conventional art can be chiefly classified into four.

Firstly, it is to try to make electromagnetic wave distribution uniform. Various ideas represented by stirrer blade, turntable are announced as patents. The trials are too many to mention.

Secondly, a method which is used widely in the conventional cooking operation using fire is used as it is. Wave concentration onto one portion is prevented or a high temperature portion, an excessive heating portion are cooled so as to make them uniform. Aluminum foil is used as the wave concentration prevention so as to effect a wave shielding operation. Defrosting the frozen foods in cold winds is introduced as a cooling method in the USP 3536129.

Thirdly, what is generally called weight-defrosting or weight-cooking is widely used. A heating operation is effected with the irradiation power quantity, irradiation time of optimum waves in accordance with food weight, foods are left without wave application for an optimum standing time to be followed by it, temperature unification of the temperatures is effected by the thermal conduction of the food interior. The USP 4,453,066 is one of the examples.

Fourthly, the temperature of the food is detected so as to control the wave application. There are patents such as the USP 3,634,652 (foods are retained at a given temperature or lower with the use of a sensor), and the USP 4,785,824 (optical fiber thermometer is used) in addition to the USP 2,657,580 (multirange thermometer). There is announced in, for example, Japanese Patent Laid-Open publication No. 52-17237 (a plurality of locations in food are detected in temperature, the wave output is lowered at a time point when one has reached the set temperature, and the heating is completed at a time point when the other has reached the set temperature), or the like even in Japanese Patent.

There is announced in, for example, Japanese Patent Laid-Open Publication No, 54-7641 (a method of estimating the inter temperature from the food surface temperature, a wave irradiation stop when the surface temperature has reached 5 • C at the defrosting time of the frozen food, a wave application is effected again at a time as low as 0 • C, differentiation values in time change from 5 • C to 0 • C are detected) or the like.

But it is impossible to realize to have the temperature of each portion of the food within several degrees C or lower, although it is not said that 1 • C or lower is necessary in difference, with respect to the desired finish temperature at a heating completion time by these methods.

The difficulties will be described briefly although the details are described later. As those skilled in the art knows well that it cannot be realized, and it is difficult only by each of the above described methods, they will be omitted.

If, for example, the temperatures of each portion of the food can be measured correctly as a combination art, it can be easily realized by an advanced controlling method using computers in an

estimation controlling operation or the like. However, only one portion becomes 65 °C if a heating operation is effected to, for example, 65 °C, or the other portion remains as it is left cold without being heated (described later in detail).

Although relative good results are obtained even in a method of gradually reducing with time lapse of high frequency application power to be used in defrosting operation, latent heat of 80 calories in 0 °C becomes a buffer in the defrosting operation. The difference to the desired temperature of the finishing is large and also, the temperature difference of each portion of the food is also large, because there are various dispersions even in the application of it to the vacuum cooking portion. Even in unequality where +10 °C or -10 °C dispersion is caused in the interior of the food by the heating operation with -0 °C as a target in, for example, defrosting operation, the + side results between - 10 °C through 0 °C, because 0 °C is maintained while the latent calory does not exceed 80 calory.

In the vacuum cooking operation, a heating operation is effected with, for example, a finish temperature of 65 °C as a target, and unequality of +10 °C or -10 °C is caused, the dispersion becomes 55 °C through 75 °C.

A flat food like a flat tongue becomes more uniform so that it is said to be completely unsuitable for a high frequency heating operation.

Even if a uniform heating operation can be realized with respect to a specific food with the use of a specific appliance, it is often that a uniformity operation is effected with resect to the other general food.

SUMMARY OF THE INVENTION

Accordingly, the present invention has been developed with a view to substantially eliminating the above discussed drawbacks inherent in the prior art and has for its essential object to provide an improved microwave heating method and apparatus.

Another important object of the present invention is to contract the temperature difference between a desired finish temperature and each portion of a food by 1 °C and by approximately several °C at maximum.

In accomplishing these and other objects, the present invention takes the following means.

A high frequency heating apparatus comprising a heating chamber for accommodating the heated, a high frequency irradiation source for irradiating the high frequency into the heating chamber, a surface temperature detecting means for detecting the temperature of the substantial surface of the heated, a central portion temperature detecting means for detecting the temperature of the central portion neighborhood of the heated, a controlling circuit for controlling the high frequency irradiation source, and which is characterized in that the high frequency is adapted to apply when all three conditions, while the difference between the surface temperature and the central temperature does not exceed a constant value, while the surface temperature does not exceed the finish temperature of the heated, and while the central temperature is lower by 1 °C through several °C from the finish temperature, are satisfied. Also, it is a heating method of carrying out the heating operation the same as it without the use of the temperature detecting means.

The method comprises the steps of popularizing it, time dividing, along a type of exponential function for expressing the thermal conduction within the heated, the necessary minimum high frequency energies.

As another practical construction, a surface temperature detecting means of the heated is adopted, the above described exponential function is approximated with at least three linear segments, energies E_2 and E_1 per unit time equal to each slope of two straight line segments are adapted to be applied till a temperature T_2 corresponding to the intersecting point of two straight segments of the latter half and a temperature T_1 corresponding to the finish temperature of the heated.

The heated food is grasped with a sandwich shape with an oil mat with edible oil being desired, sealed within a thin plastic film made bag as heating auxiliary tool.

A high frequency heating apparatus comprising a heating chamber for accommodating the heated, a high frequency irradiation source for accommodating the high frequency within the heating chamber, a surface temperature detecting means for detecting the temperature of the substantial surface of the heated, a central portion temperature detecting means for detecting the temperature of the central portion neighborhood of the heated, a controlling circuit for controlling the high frequency irradiation source, and which is characterized in that high frequency waves are adapted to be applies when all three conditions while the difference between the surface temperature and the central temperature does not exceed a constant value, while the surface temperature does not exceed the finish temperature of the heated, and while the central t mperature is lower by 1 °C through several °C than the finish temperature.

If the high frequency application is effected only while a surface temperature and a central temperature of first conditions do not exceed a constant value, for example, 20 °C, the temperature unequality of the interior of the heated caused by the high frequency application is eased by the internal heat conduction during the application stop so as to raise the temperature of the central portion.

As the high frequency application is effected only while the surface temperature of second conditions does not exceed the finish temperature, the temperature of each portion of the heated does not exceed the finish temperature. As the first conditions are satisfied at the same time, the temperature of the central portion is raised by the internal heat conduction of the heated.

If the temperature of the central portion tolerates a temperature lower by 1 °C than the finish temperature or some unequality by third conditions, the high frequency application is continued before it reaches a temperature lower by several degrees C. Thus, the interior of the heated becomes as uniform as 1 °C or several °C in temperature difference.

The same results are obtained if the above described heating operation is recorded and the same heated is heated by the same operation as that in the use of the temperature detecting means without the use of the temperature detecting means.

As it is popularized and the minimum necessary high frequency energies are distributed in time along the an exponential function showing the heat conduction of the interior of the heated, a partial excessive heating operation is not caused by energies more than necessary and the heating operation is uniform.

Since the output of the high frequency heating apparatus is large varied by power voltages and the output value of an individual apparatus also becomes different, the same uniform heating operation cannot be necessarily effected by the use of the other apparatus of the same type if the uniform heating operation can be realized by the use of a specific apparatus with a specific power voltage. In order to correct the dispersions, the surface temperature detecting means of the heated is adopted, the above described exponential function is approximated with at least three straight line segments, energies E_2 and E_1 per unit time equal to each slope of two straight line segments are adapted to be applied till a temperature T_2 corresponding to the intersecting point of two straight segments of the latter half and a temperature T_1 corresponding to the finish temperature of the heated. The temperature reaches a set temperature in a short time when the output of the high frequency heating apparatus is larger. It tales a long time to reach the set temperature when the output is small so that the variation of the output is corrected and the heating operation is uniformly effected.

In food flat like a tongue, high frequency waves are concentrated in its end portion so as to cause excessive heating operation, heat conduction of the food becomes less because of its flat shape, heat radiation becomes also large because of large surface area, thus becoming difficult especially in uniform heating operation by high frequency waves. If food is grasped in a sandwich shape, with an oil mat where the edible oil is desired and sealed into a thin plastic film made bag, the high frequency concentration into the food end portion is eased as the edible oil also absorbs some high frequency waves. The heat conduction is promoted into the food central portion from the excessive heating portion by the thermal conduction through the edible oil. The radiation from the food central portion surface is prevented as the food surfaces are kept warm with the edible oil. Therefore, uniform heating operation of the flat food by the high frequency waves can be realized.

BRIEF DESCRIPTION OF THE DRAWINGS

These and other objects and features of the present invention will become apparent from the following description of the preferred embodiment thereof with reference to the accompanying drawings, in which:

Fig. 1a and Fig. 1b are perspective view of a high frequency heating apparatus of the present invention and a sectional view taken along a line A-A' thereof;

Fig. 2a and Fig. 2b are a perspective view of a wire rack of the present invention and a sectional view taken along a line B-B' thereof;

Fig. 3 is an electric circuit diagram of a high frequency heating apparatus of the present invention;

Fig. 4 is a control circuit diagram of the high frequency heating apparatus of the present invention;

Fig. 5a and Fig. 5b are a perspective view of a liquid mat of the present invention and a sectional view taken along a line C-C' thereof;

Fig. 6 is an electric circuit diagram in another embodiment of the present invention;

Fig. 7 is a program flow chart in another embodiment of the present invention;

Fig. 8 is a view showing the temperature rise of a food heated by the high frequency heating apparatus of the present invention;

Fig. 9 is a program flow chart in a conventional embodiment;

Fig. 10a, Fig. 10b and Fig. 10c are illustrating graphs showing the temperature rise of the food;

Fig. 11a, Fig. 11b, Fig. 11c and Fig. lid are graphs showing the temperature rise of a food to be heated by the high frequency heating apparatus of the present invention;

Fig. 12 is a load variation characteristic graph of the high frequency heating apparatus of the present invention;

Fig. 13 is a comparison graph between an exponential function and an experiment result;

Fig. 14 is a program flow chart of the present invention;

Fig. 15 is a program flow chart in still another embodiment of the present invention; and

Fig. 16 is a program flow chart in a further embodiment of the present invention.

DETAILED DESCRIPTION OF THE INVENTION

Before the description of the present invention proceeds, it is to be noted that like parts are designated by like reference numerals throughout the accompanying drawings.

The preset invention will be described in a first embodiment with reference to drawings.

Fig. 1 shows a perspective view (a) showing an outer appearance of a high frequency heating apparatus of the present invention and a sectional view taken along a line A-A' thereof. The frequency wave heating apparatus is composed, in outer appearance, of a stainless mesh made heating chamber 11, a crystallizing glass made food placement board 12 fixed on the lower portion, a door 13 for closing a heating chamber opening, an operating portion 14 provided on the upper portion of the door, an outer box 15 for covering periphery, or the like.

A sectional view thereof will be described hereinafter. An oil mat 16 is placed on a food placement board 12 and a wire rack 17 is placed on it. Only an accompanying multicore shielding wire 18, a metallic plug 19 provided on its tip, and a metallic connector 20 fixed onto a rear face wall of the heating chamber are described here.
The wire rack will be described later in detail. The plug 19 and the connector 20 are connected to fit with each other. A pair of metallic plug and connector for RS-232C use which are widely used in personal computers at present are adopted.

The heated food 21, for example, a flat shaped tongue flounder, is placed on the wire rack 17. An oil mat 22 is further placed on it. A resin made stirrer cover 23 is fixed in the upper portion of the heating chamber. An antenna 24 and a motor 25 for rotation use thereof are secured in the upper portion. Likewise, an antenna 26 and a motor 27 for its rotation use are secured even under the food placement board 12. A waveguide 28 is provided on the top face of the heating chamber and a waveguide 29 is provided on the bottom face. A magnetron 30 is provided at the end of the waveguide 28 and a magnetron 31 is provided at the end of the waveguide 29. Each waveguide connects the magnetron with an antenna.

A fan motor 32 is provided with an view of causing the magnetron 30 to be air-cooled. One portion of the cooling winds passes through the magnetron 30 and thereafter is exhausted from an exhaust perforated group 33. One portion thereof is exhausted outsides through an air guide 34, a perforation group 35 provided in the rear face wall of the heating chamber, a perforation group 36 provided close to the door of the stirrer cover, an exhaust perforation group, an exhaust guide 37 provided in the top face wall of the heating chamber not described in Fig. 1 and a perforation group 38 provided in the rear face walls of the heating chamber. Outside cold winds are penetrated from the perforation group 39 provided in the bottom walls of the outer box and are absorbed into the fan motor 32. A fan motor (not shown) for cooling the magnetron 31 is also provided so that the winds are exhausted from the exhaust perforation group 40 provided in the reverse face wall of the outer box.

Fig. 2 is a perspective view (a) of a wire rack 17, and a sectional view (b) taken along a line B-B' thereof. The wire rack is composed of a square shaped frame 41 of a metallic round rod, an empty circular metallic rod body 42 fixedly inserted into a non-perforated hole which is opened from behind into the front side of the frame and a through hole which is opened longitudinally through to the rear side of the frame, a thermistor 43 inserted into the interior, a pair of mounting metal fittings 44 and 45 fixed in a condition for grasping the rear side of the frame, a vis 46 for fixing them, the multicore shielding wire 18 and the metallic plug 19.

The rod shaped body 42 is a metallic tube, approximately 1.3 mm in inside diameter, 0.18 in thickness, which is made by the same making method as that of, for example, an injection needle. The rod shaped body is fixedly mounted on the frame 41. The rod shaped body together with it is nickel-plated. Naturally, a thermistor 43 can be inserted in size into the tube. Two lead wires are insulted in a range positioned within at least rod grasped body 42 and are electrically connected with one core wire of the multicore shielding wire 18 within a space of a triangle to be formed with the frame 41, and a pair of mounting metallic fittings

44 and 45.

A concave portion is provided in the center of the mounting metallic fittings 44 and 45. In this portion, a metallic housing of the multicore shielding wire is grasped so as to effect the electric connection at the same time. The metallic plug 19 is also electrically connected with the metallic housing of the shielding wire. The thermistor 43, and its lead wires and so on are electrostatically shielded with the rod shaped body 42, the mounting metallic fittings 44, 45, the metallic housing of the shielding wire and the metallic plug. In the present embodiment, seven thermistors 43 are used. They are positioned near the center of the rods, which are the central seven rods of the seventeen rod shaped bodies drawn in Fig. 2.

Fig. 3 shows an electric circuit diagram, in the present embodiment, showing the combination of the wire rack 17 and the heated food 21 placed on it, and the whole electrical signals. It is connected with a lamp 54 for illumination of the heating chamber and its relay 55 for ON-OFF use through a fuse 52, a coil 53 for noise filter use from a power plug 54. It is connected with a heater transformer 56 for magnetron use and its relay for ON-OFF use. Motors 25 and 27 for antenna rotation illustrated in Fig. 1 in series with the heater transformer are connected with a fan motor 32 for magnetron cooling use and a fan motor 58 not illustrated in Fig. 1. It is branched into two. Switches 60 and 61 interlocked with the opening and closing of the door are connected in the respective branch path with the main relays 62 and 63. In the rear, short switches 64 and 65 are switched. Triode AC switches 66 and 67 are connected. Further, high-tension transformers 68 and 69 are connected. Magnetrons 30 and 31 are connected through a condenser and a diode onto the secondary side of the high tension transformer. The trigger circuit 70 and 71 are connected to gate of the triode AC switches so as to connect with the controlling circuit 72. The coils of the above described all the relays 55, 57, 62 and 63 are connected with the controlling circuit 72, likewise.

Fig. 4 is a circuit diagram of a controlling circuit 72. The primary side of the transformer 73 is connected behind the coil 53 of Fig. 3. One on the primary side is rectified, smoothed so as to generate direct current 18V and stabilized direct current 5V. They are added to the VCC and VSS terminal of the microprocessor 74. The waveform before the rectification on the secondary side is shaped by the transistor 75 and is inputted to one terminal (it is referred to as P8) of the microprocessor 74. The above described seven thermistors 43 are connected in series with a fixed resistance 76 into direct current + 5V. A connecting point with the fixed resistance is connected with the A / D conversion function attached input terminals P1 to P7 of the microprocessor. It is connected with trigger circuits 70, 71 of the respective relays 55, 57, 62, 63 and the triode AC switches illustrated in Fig. 3. The other types of inputs, outputs are connected with the microprocessor 74. They are all omitted because of complicated description thereof, because they have nothing to do with the summary of the present invention.

Fig. 5 is a perspective view (a) of an oil mat 16 or 22, and a sectional view taken along a line of C-C' thereof. It is a square type bag shaped container 82 of thin flexible resin film composed of polyethylene layer 80 of approximately 50 micron inside and a nylon layer 81 of approximately 20 micron outside. The square bag shaped container has edible oil 83 such as salad oil or the like put on the market therein and has an entrance portion 84 thermally sealed after being desired.

Fig. 6 is an electric circuit diagram in another embodiment which corresponds to the above described Fig. 3. The difference between Fig. 6 and Fig. 3 is that a personal computer 90 is used instead of the controlling circuit and an optical fiber thermometer 92 is connected through RS-232C cable 91 from the personal computer. An optical fiber type temperature sensors 93 and 94 are mounted on a thermometer 92. Two sensors 93 and 94 are guided into a heating chamber through orifices opened in the side wall of the above described heating chamber 11 and are inserted into the heated food 21 (not shown). For example, a note type personal computer PC-9801NS / T manufactured by NEC is used. Specific note station and input, output board such as MM-86, PI016I manufactured MSE are used or interface with resect to the relay. For example, a model 755 manufactured by Lackstron is used as an optical fiber thermometer.

Description of a hardware will be finished, and three types of control programs will be described hereinafter. First, respective intentions, ideas will be described for easier understanding thereof. They will be described together with their functions.

Fig. 7 is a schematic flow of a control program to be used by the personal computer in the embodiment having the electric circuit of Fig. 6. A first temperature sensor 93 of the optical fiber thermometer is inserted into a portion where the heated food becomes highest at temperature, generally into the surface of the heated food. The temperature is assumed to be H. A second temperature sensor 94 is inserted into a portion where the temperature becomes lowest, generally into the center and its vicinity of the heated food. The temperatures is assumed to be L. In order to know the highest, lowest temperature portions in advance, properly heat the food of the same shape and the temperature of each portion has only to be checked.

The desired finish temperature LT_1 of the heated food and a temperature LT_2 lower by 1 °C or by several °C than it are input into a personal computer so as to memorize them. As this fact is well known, it

is omitted. Its subsequent high frequency application start will be described. Depress a start key and all the relays (55, 57, 62 and 63) are turned on. In the flow, check that both the temperature H and the temperature L are both the above described LT_2 or lower. When they are lower, a step advances onto a T side. Reference character T stands for True and means that a proposition is correct. When the proposition is wrong, a step is adapted to advance onto F (False) side. Check that the difference betwe n the temperature H and the temperature L is, for example, 20 ° C or lower. When it is lower, a step advances to the lower T side so as to turn on two triode AC switches 66 and 67.

A step returns upwards so as to pass two temperature checks LT_2 or lower and 20 ° C or lower. When the temperature difference becomes 20 ° C or more, a step advances onto the F side so as to turn off the triode AC switches. While the ON-OFF of the triode AC switches are repeated in this manner, the temperature H reaches the temperature HT_2. A step advances onto a F side and advances onto the right side of the flow.

First, a D flag is made 1. Then, both the temperature H and the temperature L are confirmed not to be LTH_2 or more. When either of them is LT_2 or lower, a step advances onto the lower T side. Then, it is checked that both are also LT_1 or lower. When both are lower, a step advances onto the lower T side. Then, it is checked that both of them are LT_2 or lower. A step advances onto the F side (right side), because the temperature H has been reached so as to check that a D flag is 0. As the D flag has been just equalized to 1, a step advances onto the side (left side) so as to turn on the triode AC switches.

A step returns upwards again so as to pass three temperature checks. When the temperature H reaches the LT_1, a step advances to the F side (right side) so as to turn the D flag into 0. The step advances downwards so as to receive the check of the D flag and advances a T side so as to turn off the triode AC switches. A step returns upwards again and passes three temperature checks. Since the D flag remains 0 if temperature H is LT_2 or more this time, the triode AC switches remains off. When the temperature H becomes LT_2 or lower, a step advances to a T side, and advances downwards. The D flag becomes 1.

While the two point control between the LT_1 and LT_2 of the temperature H continues, not only the temperature H, but also the temperature L reach LT_2. A step advances onto the top portion of three temperature checks to a F side so as to turn off the triode AC switches, turns off all the relays so as to complete the heating operation.

The operation in the embodiment will be described. Fig. 8 is a graph showing the relation between time and temperature in a case where pork of approximately 900 grams frozen to approximately 0 ° C through 5 ° C is heated to 65 ° C of a desired finish temperature. The graph shows results where 65 ° C is inputted as a desired finish temperature LT_1, 64 ° C is inputted as its lower temperature LT_2, and the pork is heated. An oil mat is used in a plate shape of approximately 1 cm in thickness. Salad oil of 500 grams is sealed, desired into a bag of approximately 23 cm in width, approximately 30 cm in length, and 0.1 mm in film thickness. Two bags are used to grasp the pork in a sandwich shape from above and below.

Heating time is two hours and thirty minutes. An integrating power value measured on the primary side of the transformers 68 and 69 is 136 wh, the temperature of respective portions of the pork is between 64 ° C through 66 ° C. It is within the difference 1 ° C or lower with respect to the finish (desired) temperature 65 ° C.

An optical fiber thermometer can measure the temperatures even in the irradiation environment of the high frequency. Relatively correct temperatures can be measured. The measured system is less in turbulence. Namely, only the inserted portion thereof is not excessively heated by the insertion thereof into the food. It is considered that a uniform heating operation can be easily realized by the high frequency within 1 ° C in temperature difference of each portion of the heated food by the combination between the optical fiber thermometer and the control art as described in the conventional art. Actually it cannot be realized.

Remove 20 ° C check from the program flow of, for example, Fig. 7 and it is the simplest. Heat with it and the result exceeds 65 ° C large as shown in Fig. 10 (a). Stop the high frequency irradiation at a time point where the temperature H has reached, for example, approximately 40 ° C and the excessive portion can be prevented. The temperature L does not rise. The highest temperature portion does not exceed 65 ° C. The lowest temperature portion is hardly heated. Things are shown in Fig. 10 (b). Irradiate the high frequency only when the difference between the temperature H and the temperature L is within, for example, 20 ° C, and a uniform heating operation within 1 ° C in difference with respect to the desired finish temperature LT_1 can be effected as shown in Fig. 10 (c) or Fig. 8.

Reason why favorable results can be obtained when the controlling operation of 20 ° C is effected will be taken into consideration.

Generally it can be estimated that specific heat of the pork is approximately 0.35, specific heat of the salad oil is also approximately 0.4. The total heat quantity of both is equivalent to water of approximately 715 cc. The heat quantity necessary for raising it from 5 • C to 65 • C is 42,900 calories. Divide it and it becomes 49.8 wh in conversion to electric energy. A ratio, to be absorbed into the heated as high frequency, of the integrating electric quantity on the primary side of the above described transformers 68, 69 is approximately 53 % by an appliance used for experiment. 136 is multiplied by 0.53 and 72.0 wh is considered high frequency application power quantity. Therefore, 49.8 / 72 = 69.1. Namely, a little over 30 % is lost. The others can be interpreted to have been absorbed into the heated.

Cook food in vacuum by a steam oven and the pork of 900 grams is heated into 65 • C in approximately two hours through approximately two hours and a half although it depends upon the set temperature of the oven. The temperature rise by the steam oven is described together with Fig. 8. An integrating power quantity of the above described 136 wh is described similarly in Fig. 8. A scale is caused to conform as 136 wh = 65 • C as dimension is different.

It can be understood that it is on a curve line where the integrating power quantity being approximately conformed to a temperature L which is the lowest temperature portion of the pork. In order to confirm whether or not the agreement between the time change of the integrating power quantity and the temperature L is universal, other food, minced pork are hardened into a meat loaf type and are further packed in vacuum. They are heated likewise with four types of weights from 100 grams to 800 grams (which are grasped between two sheets of same oil mats and are heated up to 58 • C with the use of the program of Fig. 7). The results thereof are shown in Fig. 11. From the results, the phenomena is referred to as universal.

Table 1 shows the relation between input power quantity (integrating power quantity) in the above described heating operation and the absorption heat quantity of the heated food. Fig. 12 is load fluctuation characteristics of the high frequency heating apparatus output used for the calculation.

Table 1

Quality /Weight	Minced Beef				Pork
	100g	200g	500g	800g	900g
Temperature[• C]	5-58	5-58	5-58	5-58	5-65
1. Heat quantity of meat, oil mat	29.8wh	32.7wh	41.4wh	50.1wh	49.8wh
2. Heat quantity of water equivalent to meat	6.1wh	12.3wh	30.8wh	49.3wh	62.7wh
3. Irradiation power quantity	23.5wh	41wh	89.6wh	113wh	136wh
4. Corrected value of the above	7.9wh	18.0wh	46.5wh	59.8wh	70.7wh
2/4	77%	68%	66%	82%	88%

Calculation is effected as described hereinabove with the specific heat of the beef as approximately 0.43 so as to obtain the (1) line of Table 1. In 100 grams, a value becomes larger than the input power quantity of the (3) line. The (2) line shows heat quantity of water equivalent in weight to meat. It is assumed to be an absorption heat quantity. The value is adopted, because an approximately similar tendency is provided (description is omitted) even when the oil mat is not used. The irradiation (input) power quantity of the (3) line is a value on the primary side of the transformer as described hereinabove. In order to convert it into the high frequency wave irradiated into the heating chamber, it is converted into the high frequency output quantity with the use of fluctuation characteristics, namely, efficiency characteristics with respect to the water load quantity of the high frequency heating apparatus output shown in Fig. 12, thus resulting in the (4). In the calculation of (2)/(4), it is between 66 % and 88 %.

Apply, with high frequency, heat quantity of approximately 25 % extra which is necessary to raise the water the same in weight as the heated food to the desired finish temperature, with time distribution along the temperature rise curve of the central portion, for time necessary for cooking in vacuum with a steam oven, and the uniform heating operation approximately same in extent as that of the steam oven can be effected. The above described temperature difference 20 • C control introduction is considered to have the time distribution closer to that in the steam oven. The uniform heating operation equivalent to the steam oven can be realized by the time distribution of the necessary minimum high frequency energies, along the rule of the heat conduction, by the positive use of the heat conduction of the heated food interior.

When the 20 °C controlling operation is not introduced, it is considered that the irradiated energies are consumed except for the heat conduction of the heated food interior. For example, the heat of the surface portion excessively heated is emitted into air. The heat is hardly conducted into the interior of the food.

The temperature rise in a boiled bath and a steam oven is said in accordance with the following one type of exponential function. Assume that the heated is an infinite plate or ball. It is solved in accordance with a heat conduction rule, and time t is restricted to a sufficiently large range. It is simplified.

$$(\theta_w - \theta) / (\theta_w - \theta_o) = \exp(-kt)$$

where
- θ_w: inside temperature of hot water of a boiled bath or a steam oven
- θ : inside temperature of the heated food
- θ_o: initial temperature of the heated food
- k : proportional constant (which is different in boiled bath and steam oven)
- t : lapse time after heating start

Fig. 13 is a graph where the rise of the inside temperature when the above described pork of 900 grams has been cooked in vacuum by a steam oven is compared with a curve line where the value of a proper k is substituted into the above described equation. They almost conform although an error exists somewhat at the early heating stage..

If the heat quantity (high frequency irradiation power quantity) distribution along the above described equation is effected without the use of the optical fiber thermometer, it is considered that the average, equal heating operation of the boiling bath and the steam oven can be realized. Fig. 14 will be described as the control program flow.

The control program flow of Fig. 14 is applicable to a high frequency heating apparatus having circuits where an optical fiber thermometer is omitted from the electric circuit diagram of Fig. 6. When the program is started, the weight of the heated food (which is assumed to be w), desired finish temperature rise (a value where an initial temperature θ_o is subtracted from the desired finish temperature θ_1 of the food is assumed to be θ) and a heating time (which is assumed to be τ) to be spent for temperature rise are inputted into a personal computer 90. The calculating operation is effected (basic is basically used in expression). A desired temperature rise value θ is multiplied by food weight w. It is multiplied by 1.25 in anticipation of the above described 25 % loss. It is divided by 860 for conversion into the power quantity. The high frequency power quantity to be irradiated into the hating chamber can be calculated by the calculation provided so far.

Although the time distribution is effected in accordance with the above described exponential function, it is realized by the combination between the short time irradiation and the irradiation stop in terms of software, because an appliance capable of non-stage power adjustment is very difficult to make in terms of hardware. It is divided by nominal high frequency output value (rated output value) for calculation of the irradiation total time and is multiplied by 3,600 seconds. The irradiation time is made constantly 3 seconds where favorable results are obtained by experiments. It is divided by 3 and the fractions are emitted. A Yen mark ¥ shows division thereof (however, expression peculiar to Japan). The total frequency no of three second irradiation is obtained by it.

In order to assign the No frequency to the time τ in accordance with the exponential function, time required to reach to a temperature lower by 1 °C than the desired temperature is substituted as τ,

$$\text{first time} \quad t_1 = \log(1 - 1 / No) ¥ (1 / \tau * \log(1 / \theta))$$

$$\text{nth time} \quad t_n = \log(1 - n / No) ¥ (1 / \tau * \log(1 / \theta))$$

It is obtained till No-1st time and is stored.

The food is put into the heating chamber in this condition. Wait for the start key to be depressed. After the depression thereof, turn on, first, a relay so as to store undefined t_o as 0. The number counter is assumed to be n = 0. Confirm the time lapse from the depression of the start key so as to confirm that time does not reach t_n time showing the number counter. Although the lapse time is 0 as it is immediately after the start. As the t_o time is also 0, the step advances onto the N side so as to turn on a triode AC switch. Confirm that the lapse time does not reach t_n + 3 seconds and turns on a loop until it reaches. When it reaches the time, a step passes a N side through so as to turn on the triode AC switch again. The number counter advances one by one while turning on, off the triode AC switch. When the number counter

n reaches No-1, the step passes through the N side to turn off the relay for completion thereof.

A heating operation is effected with the use of the control program. As a result, the temperature difference of the interior of the food is small and the temperature of the food varies each time. Change the above described loss 25 % like, for example, 15% or 35% with the use of the same food as in material quality and shape so as to repeat trial and error often and the temperature becomes closer to the desired temperature. But it is difficult to stably have difference within 1 • C.

In order to obtain the stable result, a method of controlling high frequency irradiation quantity while monitoring the temperature of the heated food is required. A thermistor within the wire rack is provided for the object.

In the above described heating flow operation, the high frequency irradiation quantity is distributed in time along the exponential function, namely, curve line. In order to control the high frequency irradiation, the curve line is approximated with about three straight line segments and the temperature in the intersecting points of the straight lines is monitored so that the controlling operation is easy to effect. Although the approximating method is various, the curve line is approximated with three straight line segments with Fig. 10 as reference. As the exponential function passes one tenth of the heating time, approximately one third of the temperature rise and three tenths of the heating time, approximately two thirds of the temperature rise, the straight lines are three with two becoming intersecting points. In the respective straight lines, high frequency irradiation time is all three seconds and the irradiations stop time is respectively A, B or C seconds.

A method of deciding these constants will be described with the flow of Fig. 15. It is the same as Fig. 14 before the No is obtained. Then, A is obtained. A divides the τ / 10 by No / 3. Remainder is emitted in fractions (expressed by the above described Yen ¥). Thereafter, three seconds are subtracted. Similarly, B divides (3τ / 10) with No / 3. Remainder is emitted in fractions. Thereafter, three seconds are subtracted. The C divides (τ-3τ / 10) with No / 3. Remainder is emitted in fractions. Thereafter, three seconds are subtracted. A step advances to Fig. 16.

Fig. 16 a schematic flow of a control program after the start key has been depressed. Confirming that the output value (voltage value showing the thermistor 43 provided on the wire wrack 17) of the food surface temperature detecting means does not reach the T / 10 (T_3), first, all the relays are turned on. Periodic operations (which are assume to be high frequency energies of E_3 per unit time) of three seconds on, A second off are continuously repeated. T is a value where the value T_o initial (before the heating) of the food has been subtracted from the output value T_1 when the heated food whose temperature reaching the finish temperature θ_1 is measured by the food surface temperature detecting means. A step advances onto the F side after the output value has reached the T / 10 (T_3). Confirming that it does not reach 3T / 10 (T_2) this time, a periodic operation (which is assumed to be high frequency energies of E_2 per unit time) of three seconds on, B seconds off is continuously repeated. After it has reached, a step advances onto the F side. Confirming that it has not reached T_1 this time, a periodic operation (likewise, E1) of three second on, c second off are continuously repeated. After it has reached, a step advances onto the F side. All the relays are turned off so as to come to end.

The difference 1 • C or lower with respect to the desired temperature is stably obtained as in a case where a optical fiber shown in Fig. 6 is used when a cooking operation is effected by a method of the sectional view shown in Fig. 1 with the use of the control program by the flow.

The above description is arranged with some supplements as follows.

(1) A heating operation within 1 • C in temperature difference cannot be effected if the highest temperature portion (surface portion) and the lowest temperature portion (central portion) of the food are controlled with high frequency with the conventional method, monitoring temperatures with the use of two measuring means which does not give influences to the measured system of the optical fiber temperature meter.

(2) A heating operation within 1 • C or lower in temperature difference can be realized when a method of stopping the high frequency irradiation if the temperature difference between the high temperature portion (surface portion) and the low temperature portion (high temperature portion) is made larger by, for example 20 • C or more, and effecting an irradiating operation again if the temperature difference becomes 20 • C or lower again.

(3) Although the above description is sufficient as a heating operation at a constant time, a problem remains as a vacuum cooking operation. Although the optical fiber is required to be inserted into the food central portion for measurement of the lowest temperature, there is a risk of lowering the vacuum degree when a resin bag for vacuum pack is passed through. In order to prevent it, a kind of packing with sponge bonding agent being attached to it is used conventionally when a thermometer is thrust. A sensor portion of the optical fiber thermometer is weak in waist. It can be thrust by experiments in a laboratory,

but it is inconvenient in using the packing in a kitchen. A method of effecting an operation is required without a thermometer being inserted into the interior of the food.

(4) In the controlling operation with the use of the above described optical fiber thermometer, the heating time is approximately equal to the time of cooking by the steam oven. The temperature rise of the lowest temperature portion of the food is also similar to the temperature rise by the heat conduction of the heated food interior. The irradiation high frequency power quantity is an extent (approximately 1.25 times) where a loss portion is added to the heat quantity necessary for raising the food to the desired finish temperature. Effect time distribution, along a function showing the heat conduction of the food interior, of the necessary minimum high frequency power quantity and the uniform heating operation can be effected.

(5) High frequency power quantity of necessary minimum is divided into three seconds' high frequency continuous irradiation, and time distribution is effected in accordance with the function so as to effect a controlling operation of slowly increasing the irradiation stop time to be followed by three seconds' continuous irradiation. As a result, the finish temperature changes for each experiment although the temperature difference of the interior of the food is small. Some correcting means, for example, the necessity of the food surface temperature measuring operation is found out.

(6) A thermistor provided within the metallic wire rack is adopted as a food surface temperature detecting means. Although the measured system to be disturbed by the temperature detecting means has to be avoided most as described in the above described (1), the metallic wire rack is widely adopted conventionally in the U.S.A., the high frequency designing operation is effected so that the uniform heating operation can be realized in a condition using it.

(7) In the controlling operation with the combination with the food surface temperature, the above described function is approximated (substituted) by three straight line segments for easier controlling operation, a cyclic operation is effected till it reaches a temperature corresponding to the intersecting point of these straight lines. One period has constant high frequency energies per unit time corresponding to the slope of the straight line with respect to one straight line segment, namely, constant time, for example, three seconds' continuous high frequency irradiation and an irradiation stop of a constant time to be followed by it.

(8) Although the central temperature of the food is not directly measured, the high frequency power quantity of necessary minimum is distributed in time and irradiated along a function showing the heat conduction of the food interior. The temperature rise of the central portion approximately conforms to the rise curve line of the total irradiation power quantity, can be easily estimated, is corrected by the surface temperature measuring operation, and can be understood more correctly.

(9) By the above description, the uniform heating operation within 1 °C in temperature difference can be realized by the high frequency irradiation. The oil mat is dispensable for food flat like tongue. Stable results can be obtained with respect to the shape except for it.

In the summary of the present invention, the uniform heating operation is realized by the combination between the food surface temperature detecting means and the high frequency energies distribution along the straight line segments approximate to the functions showing the heat conduction of the food interior. Although it is made a main claim of the present invention, a uniform heating operation can be realized even in the embodiment except for it under the various conditions as described hereinabove, the scope of the claim is arranged.

A method of measuring the surface (the highest temperature) portion and the central (the lowest temperature) portion of the above described (2) paragraph and controlling the high frequency application while retaining the difference between them substantially under a constant value or lower is not inferred from the conventional art. Substantially, to be substantially constant means steps of irradiating the high frequency only the time of 25 °C or lower at, for example, an initial heating stage and of changing the temperature to 20 °C or 15 °C as time elapses. Although a two point controlling operation of LT_1 and LT_2 are effected in the embodiment in the embodiment, it is not always essential. The uniform heating operation can be effected even in one point controlling operation of LT_1 only.

It can be easily understood that the same result can be obtained if the same high frequency irradiation can be reproduced as when a thermometer is used with respect to the same food (material quality, shape, weight and so on are the same) without the use of the optical fiber thermometer or the like. As a reproducing method, there is a method of keeping the ON time and OFF time of the triode AC switches 66 and 67 recorded on a floppy disk of, for example, a personal computer 90 and then, controlling the triode AC switches along the recording at the heating time of the same food. The reproducing operation can be effected even if an operation is effected manually in accordance with it without use of the mechanical recording means. The uniform heating operation can be realized even when the high frequency irradiation

algorism of the above described (7) paragraph is adopted as it is without the use of the surface temperature detecting means as an approach different from them. A heating operation portion where the temperature difference between the highest temperature (surface) portion of the heated food and the lowest temperature (center) portion becomes substantially constant as a result by the heating operation, and a heating portion where the lowest temperature (center) portion rises towards the finish temperature without the highest temperature (surface) portion of the heated food to be carried subsequently out exceeding the finish temperature are essential.

The uniform heating operation can be reproduced similarly if it is popularized, one type of an exponential function for showing the thermal conduction of the interior of the heated food or the high frequency energies of necessary minimum are distributed in time along the function approximate to it. First, the energies of the necessary minimum will be described hereinafter.

The loss portion to be released from the irradiation energies to be considered to have been absorbed in the heated food within the heating chamber is assumed to be 25 % on the average. This depends upon the material quality, shape of the food, the weight, shape of the oil mat to be used, contact condition with the food, wind quantity within the heating chamber of the high frequency heating apparatus to be used, and so on. It is known by experiment that the temperature is lowered if the food of approximately 50 °C through 60 °C is left in the air for thirty minutes through one hour. It can be easily understood that it is promoted if wind blows. Radiation quantity is also increased naturally if the time is long.

Power quantity to be put into the food is further large as fluctuating factors. As known to those skilled in the art, the output of the high frequency heating apparatus is tolerated in difference by approximately 15 % with respect to a rated output value. The output value becomes different in a cold condition and in a condition of hot temperatures caused because of the long hours' use even if an apparatus is one. If the power voltage is fluctuated by 10 %, the output is fluctuated by 15 % or so. All things considered, the fluctuation is caused by approximately 30 % above and below. If the fluctuation is caused by 30 % from the intended high frequency power quantity, the temperature rise value of the food is also fluctuated by 30 %, because the finish temperature is decided by the input power quantity as described hereinabove. Assume that it is the temperature rise of 60 °C from 5 °C to 65 °C, and temperature becomes different as many as 18 °C.

Therefore, "high frequency power quantity of necessary minimum" is a value where these output fluctuation elements are correctly grasped and further, loss heat quantity is added to it. As an apparatus to use, the heated food, how to place them in the heating chamber, and so on are different, they have to be obtained individually. Prior to the heating operation, they have to be obtained in advance.

Heating time will be described hereinafter. A steam oven is adopted as a heating embodiment by the conventional thermal conduction where the heating operation can be effected with the same time as it by the high frequency heating operation. It is known that the boiling bath is faster in heating. Thus, it can be easily understood that the high frequency heating operation which professes a second speed heating operation originally can heat for the same time as that of the boiling bath when it is used positively as the heat conduction of the interior of the heated food. The heating time by the boiling bath is not decided unilaterally. Mr. Plaryue, an inventor of the vacuum cooking, says in his system that the heating time is considerably contracted, as the chamber interior temperature of the steam oven or the hot temperature of the boiling bath is set to approximately 15 °C from 10 °C higher than the finish desired temperature (in this case, the food circumference naturally becomes high in temperature and the above described 1 °C cannot be uniform. As, for example, roast beef or the like is vacuum cooked after the scorching mark is given on the periphery, it does not matter at all that the temperature becomes higher only in the periphery.)

The heating time τ of the boiling bath in the claim 3 includes these facts in concept. The functions showing the heat conduction of the food interior in the case of the temperature higher than such finish temperature as reference is an exponential function where a temperature higher than 10 °C or 15 °C becomes an asymptotic line, not an exponential function where a finish temperature becomes an asymptotic. The high frequency irradiation power quantity has to be distributed in time along it. As a result, the heating time naturally becomes shorter and the temperature difference between the highest temperature and the lowest temperature is also enlarged.

The heating time τ will be described hereinafter. As the vacuum cooking operation by the high frequency irradiation of the present invention is a method of positively using the heat conduction of the food interior, so that the heating speed is restricted by the thermal conduction speed of the food interior. In the case of the boiling bath, the heating time becomes longer not only by the heat conduction of the food interior, but also by the heat exchange between the hot water and the food trough a vacuum pack film. Food is faster heated in hot water when a case where the same food is put into the hot water of the same temperature is compared with a case where it is put into steam. This is because it is caused due to

difference in heat exchange performance between the water and the steam. Therefore, the heating contraction can be further effected if the heating operation is effected with an apparatus superior in the thermal exchange performance to the present boiling bath apparatus, with films or thermal media. Although the limit value is unknown, a heating operation close to the limit value of the heat exchange is considered possible to realize, because the food surface and its vicinity are directly heated by the high frequency irradiation. As an actual problem, the boiling bath is a heating means easily available. It is used to express the whole heating method using the thermal medium as it is a method capable of heating food for the shortest time among them.

Approximation of the exponential function showing the thermal conduction will be described hereinafter. The approximation by the straight line segments is simple and easy to carry out. This is because the time distribution of the heating energy in a straight line shape is to irradiate constant energies per unit time. At least two segments are required if it is approximation by straight line segments. Approximation with one straight line is simply continuous irradiation for long hours with constant low outputs. It is conventionally known to those skilled in the art that the uniform heating operation of approximately 1 °C in temperature difference cannot be effected. Accordingly, two straight lines are required at least.

A periodic operation where constant time of high frequency application and a constant time of irradiation stop to be followed by it are made one period is realistic as constant energy per unit time. Add irradiation stop time by constant value by constant value accompanied by he addition of the periodic number, and it becomes one type of curve control, and becomes closer to a function showing the heat conduction of the original food interior, thus resulting in stable results.

Approximation cannot be said to be better as it is closer to the original function. Observe the results of the control using the optical fiber thermometer of Fig. 8. At the beginning of the heating operation, the energy distribution exceeding the exponential function is effected. The portion of the shoulder of the exponential function shows energy distribution large lower and the total energy distribution becomes lower than the function near the heating completion and is larger in inclination. If energies somewhat large are added at the beginning of the heating operation, no problem is caused before approximately 20 °C in difference between the highest temperature (surface) portion and the lowest (central) portion. It is safer to have restricted energy distribution, because the portion of the shoulder of the function is a period when the highest temperature portion reaches the finish temperature. On the other hand, the heating end can have temperature rising faster than in the boiling bath and the steam oven. As the temperature difference between the heat source and the heated becomes small in the heating operation by the heat conduction as in the boiling bath, the long time is required to slightly raise 1 °C, but the high frequency heating can be contracted in time as such physical restriction is not provided.

It is a desirable direction to have energies distributed exceeding (the inclination of the straight line is larger than the average addition ratio of the exponential function) the exponential function at the beginning of the heating operation, and at the heating completion and its vicinity, and have energy distribution lower than the exponential function between them.

In order to correct the various fluctuations by the combination with the surface temperature detecting means, a method of having, as a temperature detecting means, not only wire rack having a thermistor built in it, but also having a temperature sensing portion (tip end) of, for example, above described optical fiber thermometer grasped between the food and the oil mat, and using a conventionally known infrared ray thermometer without use of ail mat. When the food is at a finish temperature θ_1, the detection value of the surface temperature detecting means becomes smaller than it. The temperature which is lower than the food temperature is detected even with the optical fiber thermometer whose difference is relatively lower because of temperature slope or the like on the wall face of the vacuum pack. In the case of the wire rack, the temperature becomes further lower because of the temperature slope by the metallic wall for constituting it. In the case of the infrared rays, the detection value is lowered by the ratio of the food area to be occupied within the visual field angle except the difference by the temperature slope. Thus, the detection value T_1 when the food is at a finish temperature θ_1 and the detection value T_0 when it is at θ_0 are required to be obtained experimentally in advance. If both are obtained, T_2 can be calculated even at the calculation as shown in the embodiment.

The computation with calculation is effective even in a case without a temperature detecting means. The heating program is obtained when the temperature T of Fig. 16 is converted into the time τ. As it is simple, it is not illustrated in particular.

Although the irradiation time is 3 seconds in total, it is considered due to a fact that the high frequency output of the apparatus of Fig. 1 used in the experiment is approximately 1000 W. Although an optimum value is changed if the output value is different, an excessive heating operation is generated when an irradiating operation is effected for a long time. Although it is considered that the optimum time depends

upon the type, shape, weight of the hood, the quality, output value or the like of the high frequency heating apparatus to be used, and so on. As experiments cannot be made actually, it is claimed with twice as long as 3 seconds as a top limit. 7 seconds or more are not included in claims accordingly.

An apparatus has a high frequency irradiation source (rotary antenna) on both the top face and the bottom face of the heating chamber in the embodiment of Fig. 1, because this system stably provides heating results in design easily so that the temperature becomes the lowest in the central portion with respect to the heated food of the various shapes (simply speaking, a uniform heating design is easier to operate). Although the system is not an essential requirement of the present invention, it is needless to say that the heating results are deteriorated in such an apparatus where food may move to a different position in its lowest temperature portion.

The present invention is described with a view to the vacuum cooking. It uses positively the heat conduction of the food interior. In the case of food not packed in vacuum, there is a uniform heating effect with things being similar completely although the heat conduction time is different. Although the necessary minimum of energies and heating time are large different even in the defrosting operation of the frozen food, the effect of the uniform heating operation is the same. Although not only the food, but also the heated such as resin products are considered considerably different naturally in the energies and heating time of necessary requirements in the case of heating operation and so on. As the thermal conduction and the high frequency heating operation are same in basic principle, it can be used for it.

As is clear from the foregoing description, according to the arrangement of the present invention, the uniform heating operation of approximately 1 °C in temperature difference can be realized, and considerable fuel cost reduction can be effected and also, operation environment can be large improved as compared with a vacuum cooking operation using the conventional boiling bath and the steam oven.

Although the present invention has been fully described by way of example with reference to the accompanying drawings, it is to be noted here that various changes and modifications will be apparent to those skilled in the art. Therefore, unless otherwise such changes ad modifications depart from the scope of the present inventions, they should be construed as included therein.

Claims

1. A high frequency heating apparatus, comprising a heating chamber for accommodating the heated, a high frequency irradiation source for irradiating high frequencies into the heating chamber, a surface temperature detecting means for detecting the temperature of the substantial surface of the heated, a central portion temperature detecting means for detecting the temperature of near the central portion of the heated, a control circuit for controlling the high frequency irradiation source, is adapted to apply high frequencies in filling all three conditions while the difference between the surface temperature and the central temperature does not exceed a constant value, while the surface temperature does not exceed the finish temperature of the heated, and while the central temperature is lower by 1 °C through several °C than the finish temperature.

2. A high frequency heating apparatus as defined in claim 1, where an optical fiber thermometer is used as the surface temperature detecting means and the central portion temperature detecting means.

3. A heating method of using a high frequency heating apparatus having a heating chamber for accommodating the heated, a high frequency irradiation source for irradiating high frequency within the heating chamber, a controlling means for operating the application source for few seconds, including at least the following procedures of

(1) effecting a periodic operation where several seconds' high frequency irradiation and a constant irradiation top time to be followed by it are made one cycle, in such a member that these irradiation time, irradiation stop time and periodic operation number are assumed as values decided to substantially maintain constant values in the temperature difference between the central portion and the surface portion of the heated

(2) effecting a periodic operation where several seconds' high frequency irradiation and a constant irradiations stop time to be followed by it are made one cycle, in such a member that these irradiation time, irradiation stop time and periodic operation number are assumed as values decided where the temperature of the surface portion of the heated is a finish temperature or lower, and the temperature of the central portion should reach several degrees °C lower than 1 °C of the finish temperature.

4. A heating method of using a high frequency heating apparatus having a heating chamber for accommodating the heated, a high frequency irradiation source for irradiating high frequencies within the heating chamber, of heating in the following procedures of,

(1) obtaining previously the minimum high frequency energy quantity Q necessary enough to raise the heated to the finish temperature,

(2) obtaining previously the heating time τ when the heated has been boiled,

(3) irradiating the following functions showing the relation between the time t and the total high frequency energy q irradiated on the heating chamber up to that time

$$q / Q = 1 - \exp\{(t / \tau) \times 1n (\Delta\theta / \theta))$$

where $\theta = \theta_1 - \theta_0$ (θ_0: initial temperature of the heated, θ_1: finish temperature) $\Delta\theta$: temperature difference of the interior of the heated or irradiating for τ time the high frequency energy quantity Q distributed in time along a function approximate to it.

5. A high frequency heating method as defined in claim 4 comprising the steps of including at least three time regions, approximating by a function having a slope larger than the average slope of the function in first and third time regions, approximating with a function of a slope smaller than the average slope of the function in the second time region to be grasped therebetween.

6. A high frequency heating method as defined in claim 4 comprising the step of having the time distribution of the high frequency irradiation energies composed of discontinuous, namely, approximate several seconds of high frequency irradiation and irradiations stop to be followed by it.

7. A high frequency heating apparatus comprising a heating chamber for accommodating the heated, a high frequency irradiating source for irradiating the high frequency into the heating chamber, a surface temperature detecting means for detecting the temperature of the heated surface, a control means for controlling the high frequency irradiation source, characterized in that the controlling means is adapted to control the high frequency irradiation source with a signal from the surface temperature detecting means so that the surface temperature of the heated may supply given second high frequency energies E_2 per unit tame into the heating chamber in a temperature region of the given second temperature T_2 or lower, or may supply into the heating chamber first high frequency energies E_1 lower than the second energies E_2 or energies to be reduced in monotony from E_1 as time passes in a temperature region between the second temperature T_2 or more and the heating completion temperature T_1 of the heated.

8. A high frequency heating apparatus as defined in claim 7, where high frequency energies E_1 and E_2 are a slope of latter half two straight line segments when a following function is

$$q / Q = 1 - \exp\{(t / \tau) \times 1n (\Delta\theta / \theta))$$

where $\theta = \theta_1 - \theta_0$ (θ_0: initial temperature of the heated, θ_1: finish temperature of the heated) $\Delta\theta$: temperature difference of the interior of the heated

- τ : total time necessary for heating
- t : time
- Q : high frequency energy necessary for raising the temperature by the heated by θ
- q : total high frequency energy to be irradiated between the heating start and time t

has been approximated with at least three straight line segments, or the surface temperature T_1 and T_2 correspond to the contact points of the final segments, and are the output value of the surface temperature detecting means when the heated reaches the finish temperature θ_1.

9. A high frequency heating apparatus as defined in claim 8 where a slope of first and third straight lines is made larger than the average slope of the function in these time regions, the slope of the second straight line to be grasped between them is made smaller than the average slope of the function in the time region.

10. A high frequency heating apparatus as defined in claim 7 where a temperature sensing element such as thermistor or the like is provided therein as the heated surface temperature detecting means, wire

rack composed of several rod-shaped empty metallic bodies are used so that they may approximately parallel and be the same plane in the top portion.

11. A high frequency heating apparatus as defined in claim 7 where the heated is heated in a condition grasped in a sandwich shape with a plate shaped oil mat having edible oil desired, sealed within the thin plastic film made bag as a heating auxiliary tool.

12. A high frequency heating apparatus as defined in claim 11 where the temperature sensing portion of the heated surface temperature detecting means is placed between the heated and the oil mat.

13. A high frequency heating method as defined in claim 3 having a step of heating the heated in a condition grasped into a sandwich shape with a plate shaped oil mat having edible oil desired, sealed within the thin plastic film made bag as a heating auxiliary tool.

14. A high frequency heating method as defined in claim 4 having a step of heating the heated in a condition grasped into a sandwich shape with a plate shaped oil mat having edible oil desired, sealed within the thin plastic film made bag as a heating auxiliary tool.

Fig.1a

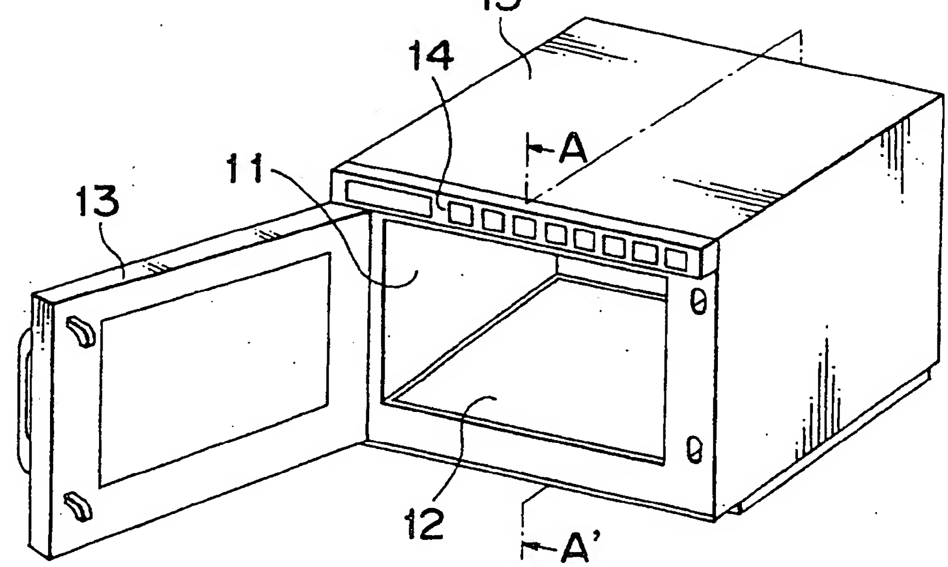

15
14
A
11
13
12
A'

Fig.1b

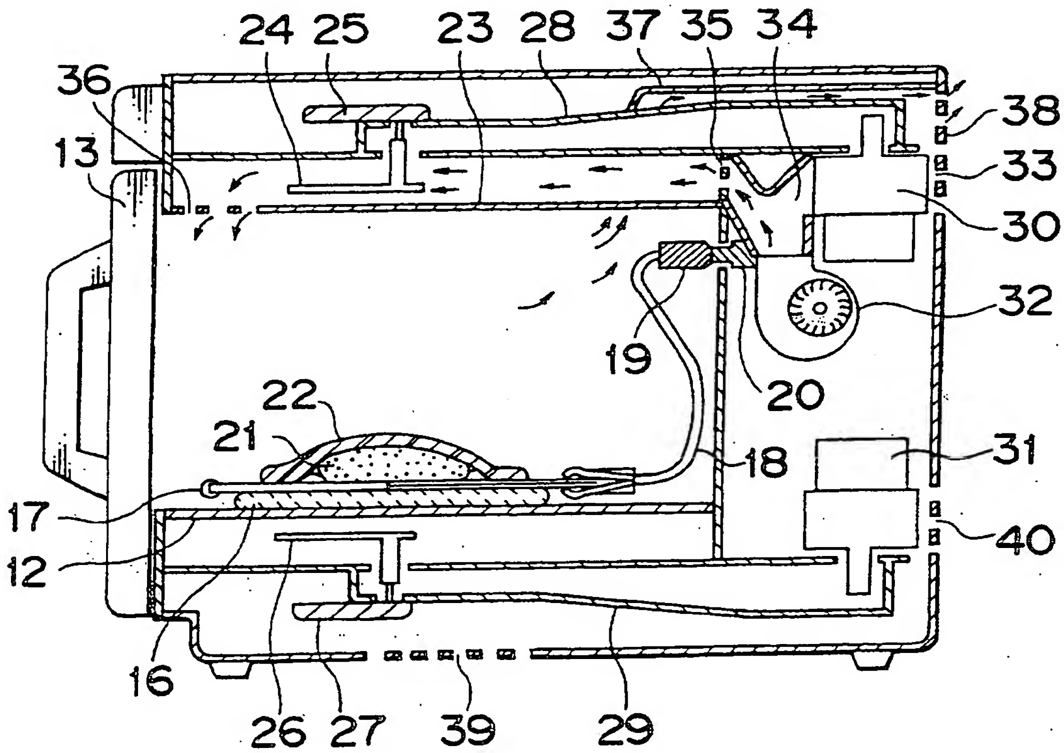

24 25
23 28
37 35 34
36
38
13
33
30
32
19
20
22
21
31
18
17
40
12
16
26 27
39
29

Fig.2a

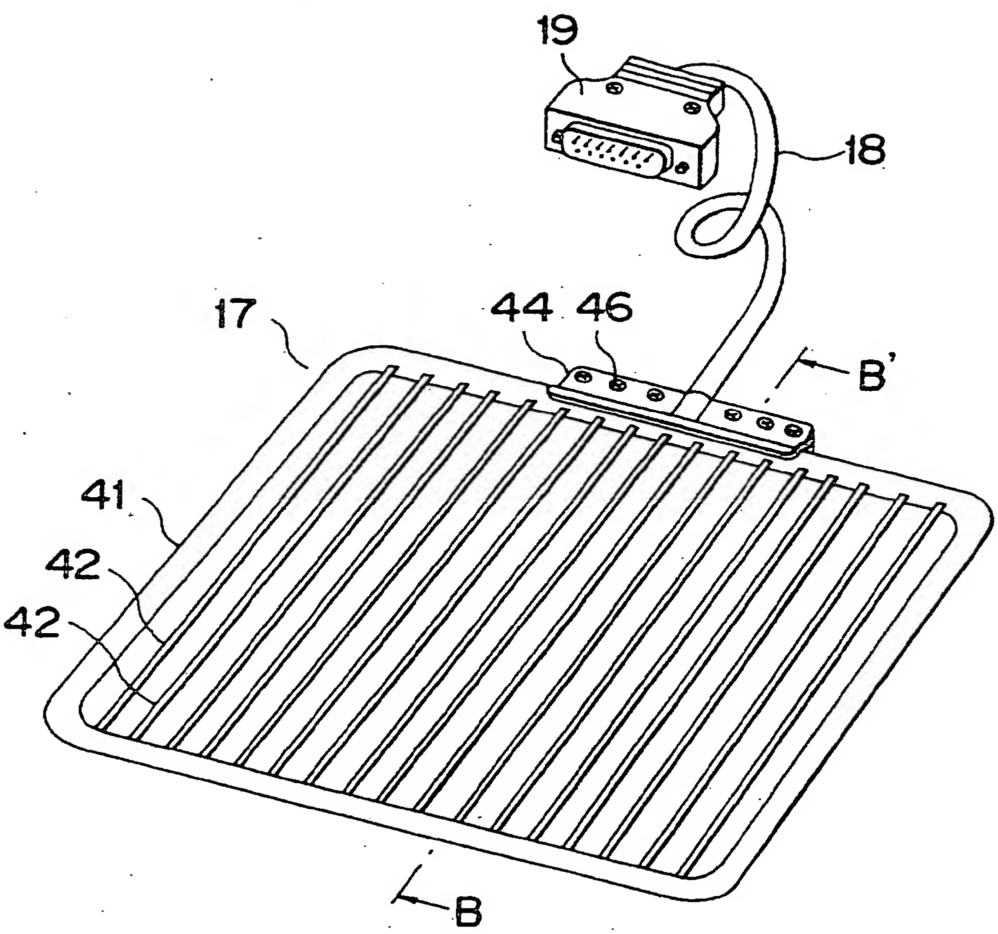


Fig.2b

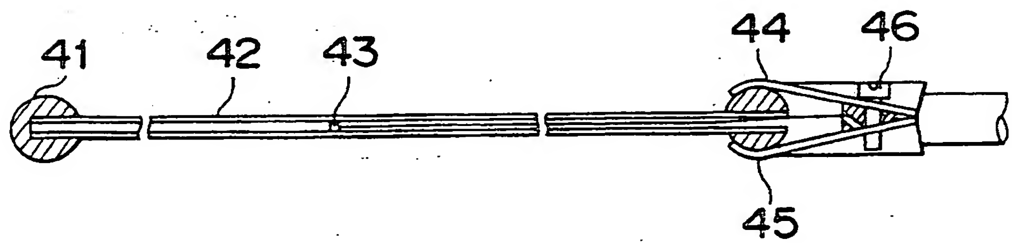
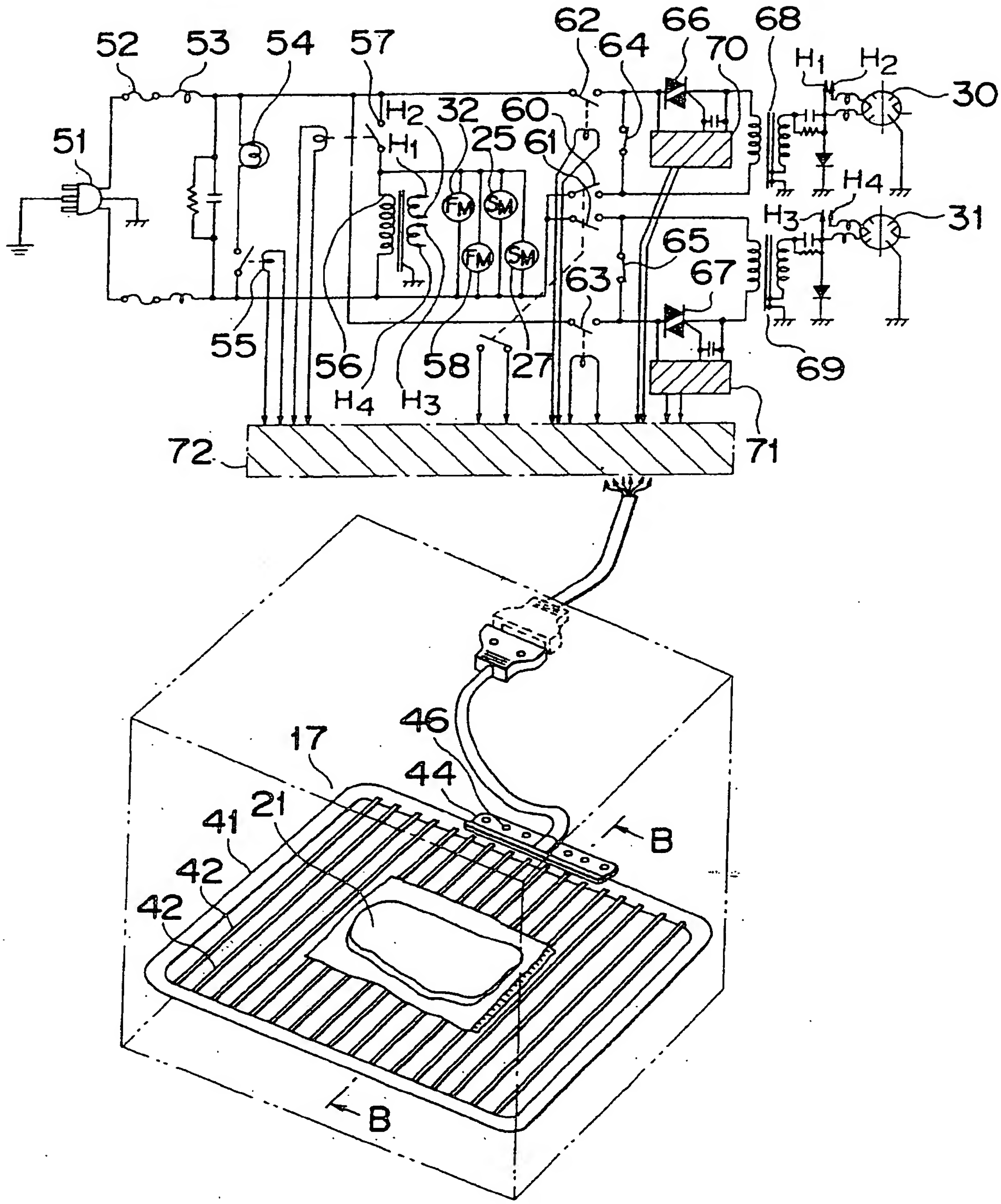


Fig.3


52
53
54
57
62
64
66
70
68
H1
H2
30
51
H2
32
25
60
61
H1
FM
SM
FM
SM
H4
H3
H4
31
65
67
63
55
56
58
27
69
H4
H3
72
71
46
17
44
21
41
42
42
B
B

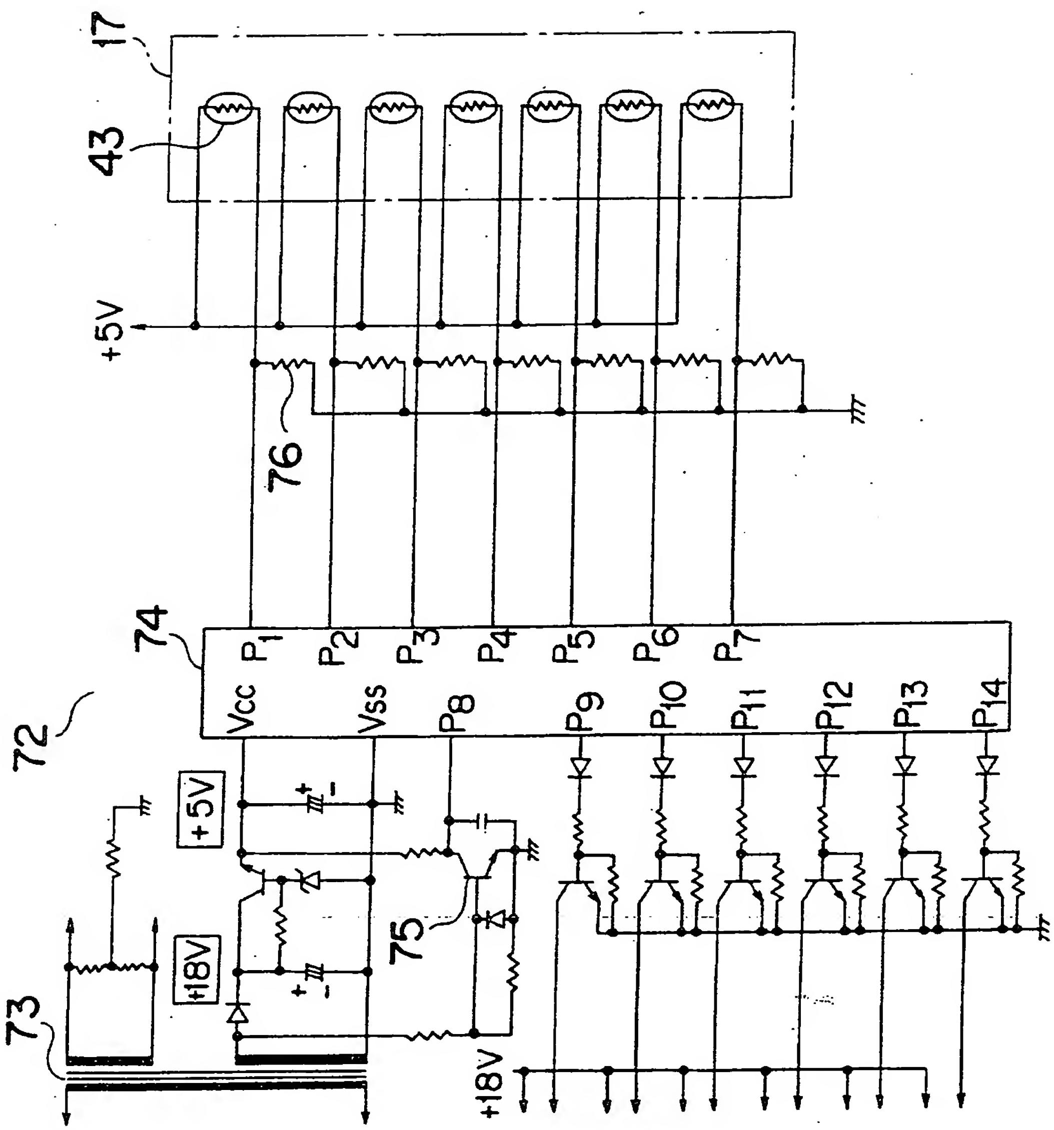

17
43
+5V
76
74
72
P1
P2
P3
P4
P5
P6
P7
Vcc
Vss
P8
P9
P10
P11
P12
P13
P14
+5V
+18V
73
75
+18V

Fig.4

Fig.5a

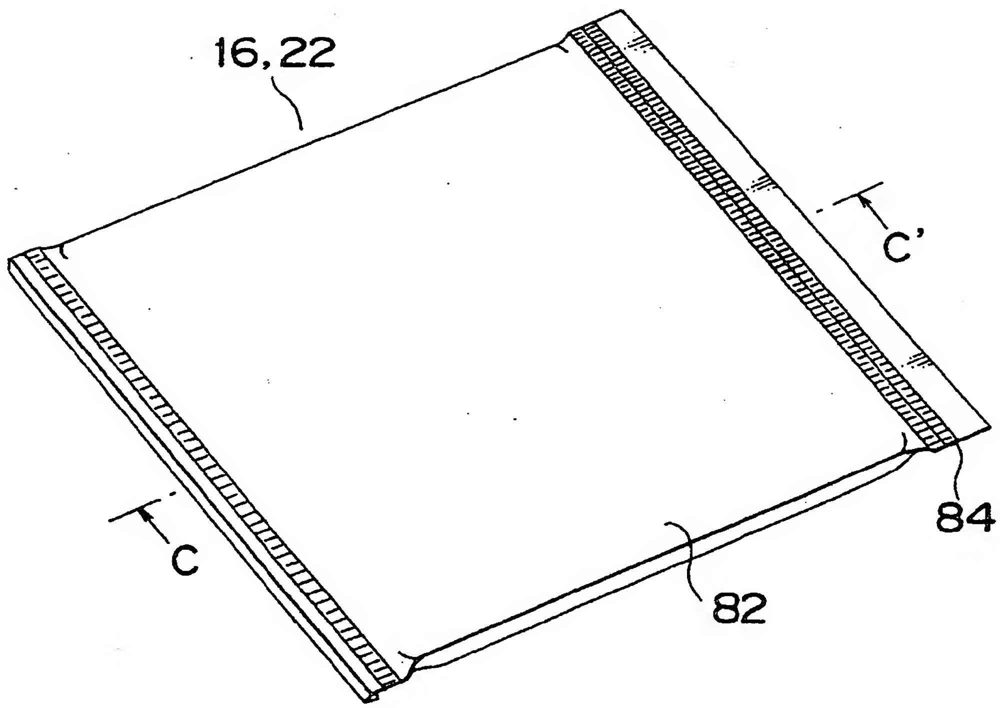


Fig.5b

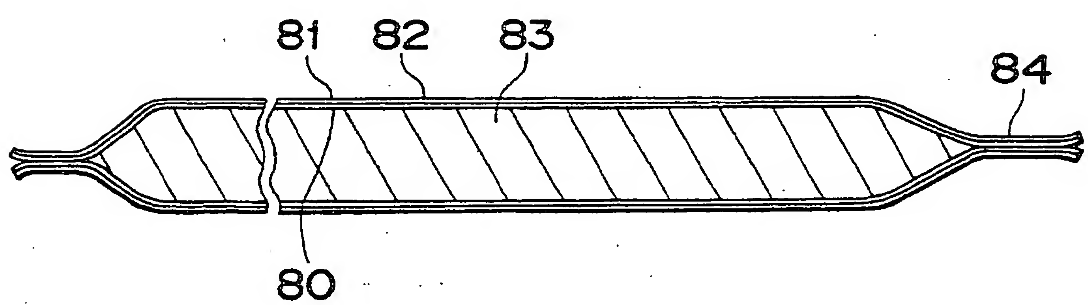
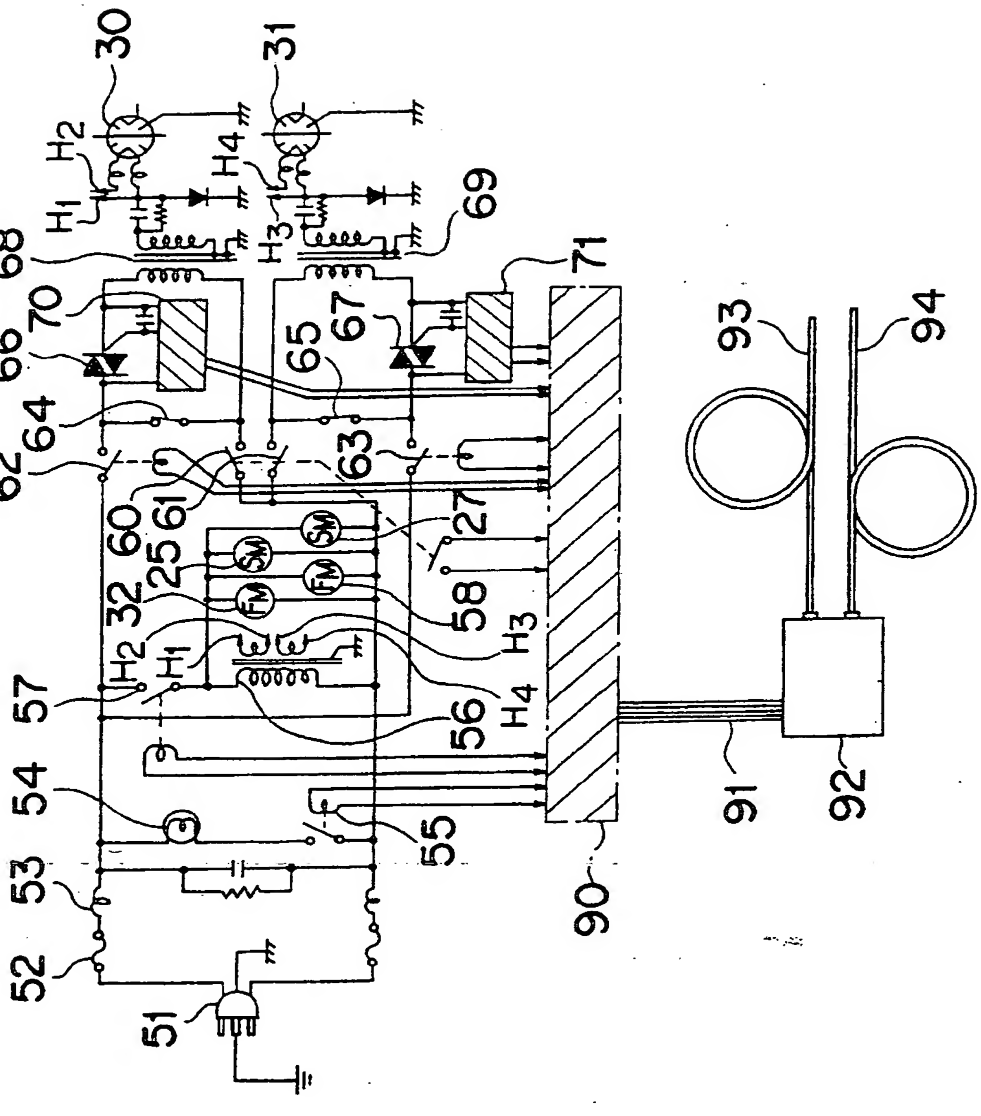


Fig.6


30
31
H2
H1
H4
H3
68
69
70
66
71
65
67
64
62
63
60
61
27
25
32
SM
FM
58
56
57
54
55
53
52
51
90
91
92
93
94

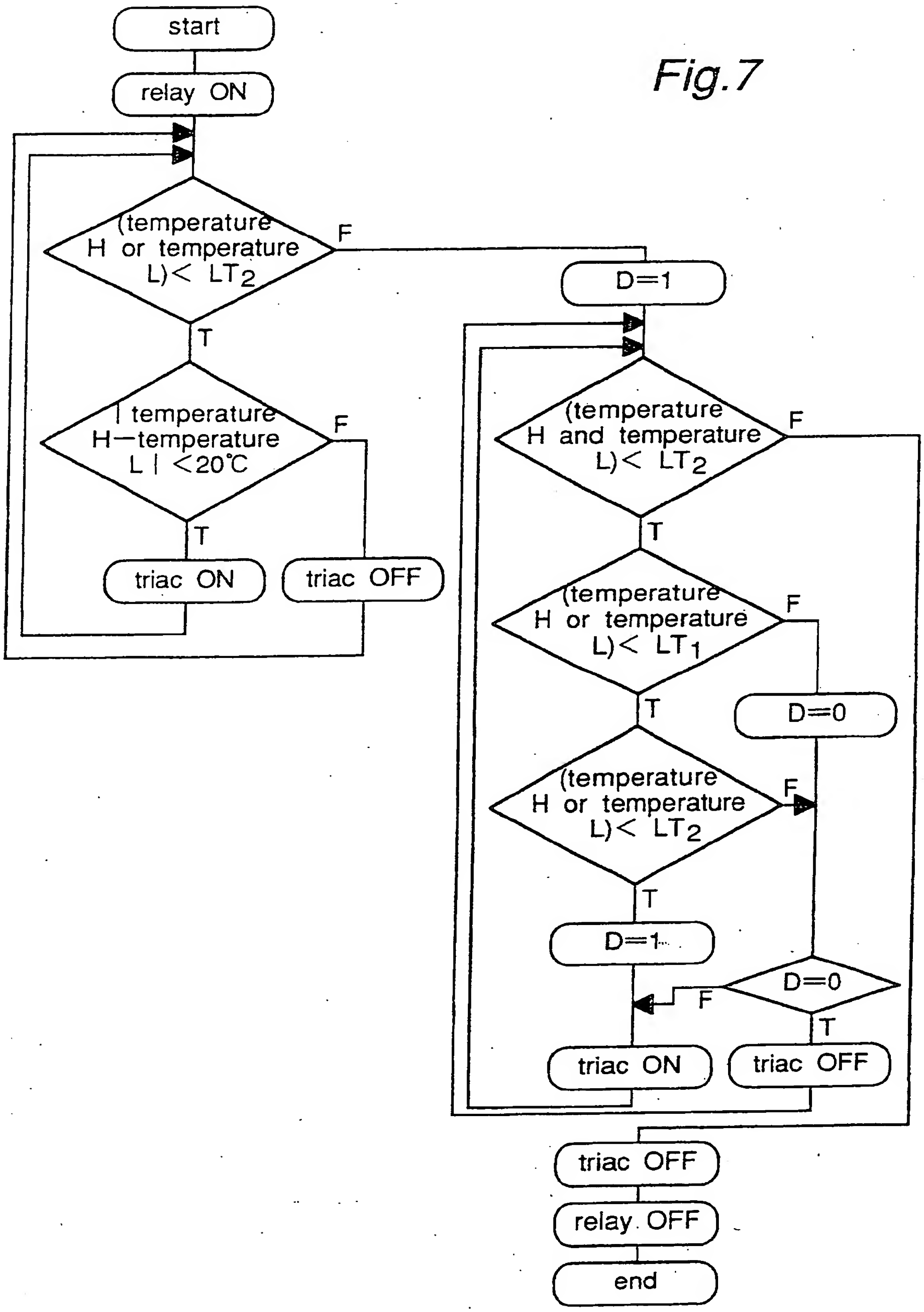
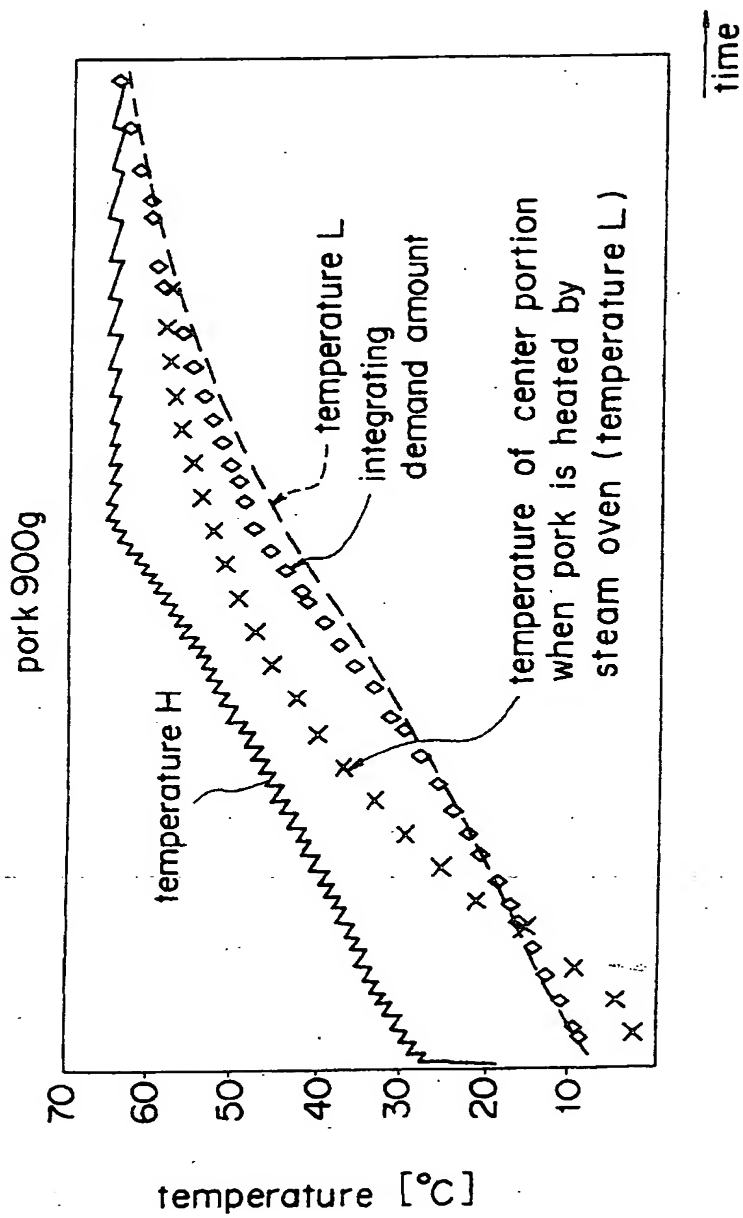

start
relay ON
(temperature H or temperature L)< LT2
F
T
\| temperature H—temperature L \| <20℃
F
T
triac ON
triac OFF
D=1
(temperature H and temperature L)< LT2
F
T
(temperature H or temperature L)< LT1
F
T
D=0
(temperature H or temperature L)< LT2
F
T
D=1
D=0
F
T
triac ON
triac OFF
triac OFF
relay OFF
end

Fig.7

Fig.8


pork 900g
temperature H
temperature L
integrating demand amount
temperature of center portion when pork is heated by steam oven (temperature L)
time
temperature [°C]
70
60
50
40
30
20
10

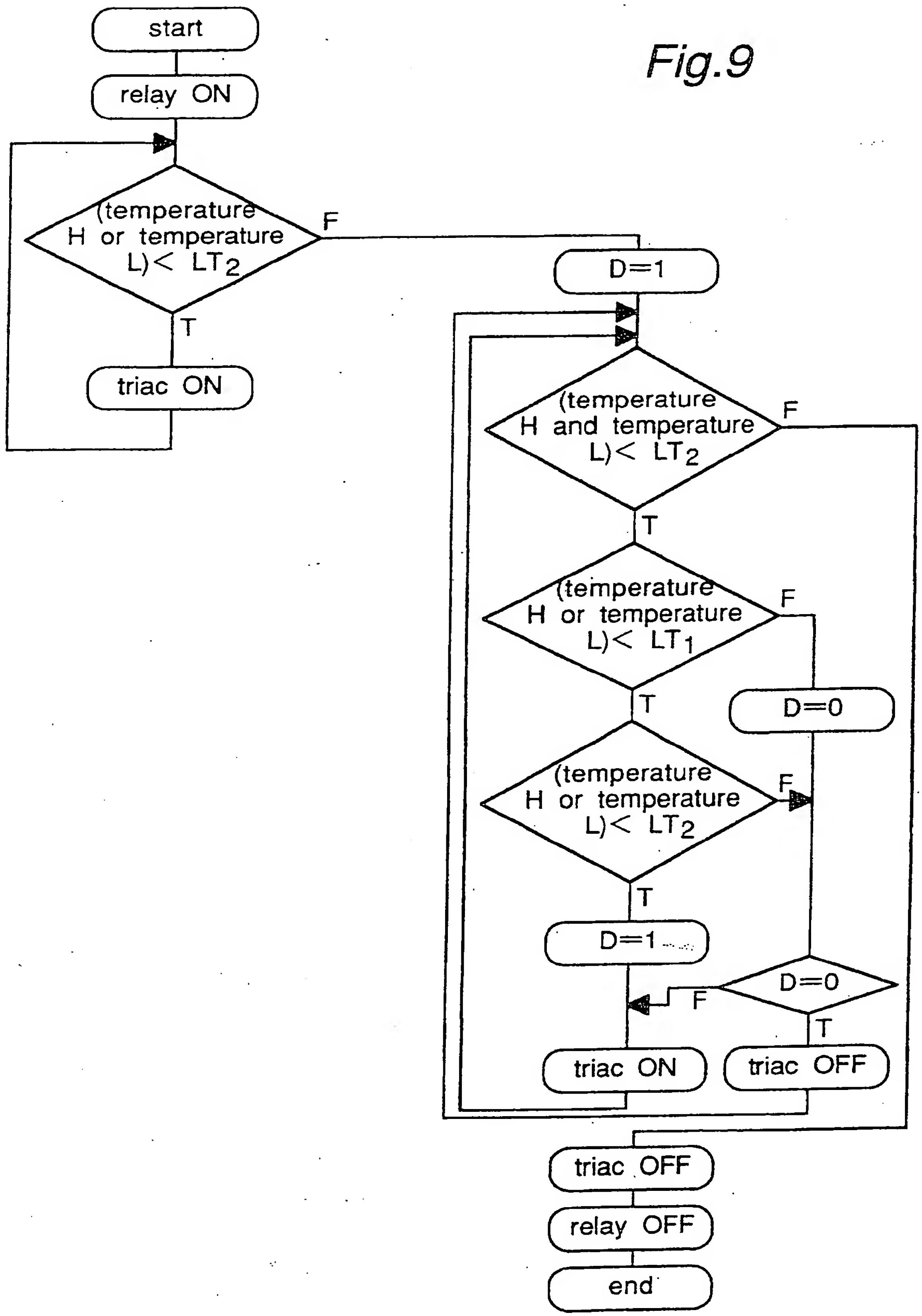

start
relay ON
(temperature H or temperature L)< LT_2
F
T
triac ON
D=1
(temperature H and temperature L)< LT_2
F
T
(temperature H or temperature L)< LT_1
F
T
D=0
(temperature H or temperature L)< LT_2
F
T
D=1
D=0
F
T
triac ON
triac OFF
triac OFF
relay OFF
end

Fig.9

Fig.10a

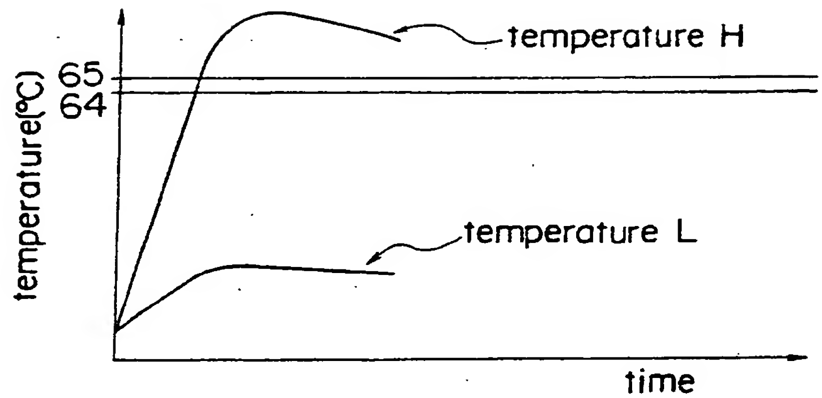


Fig.10b

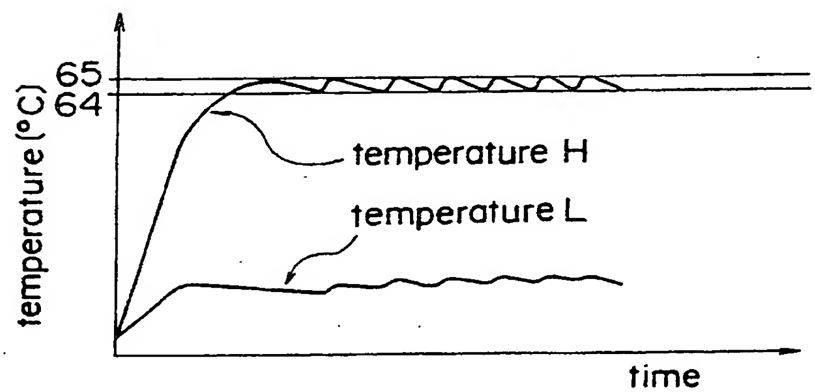


Fig.10c

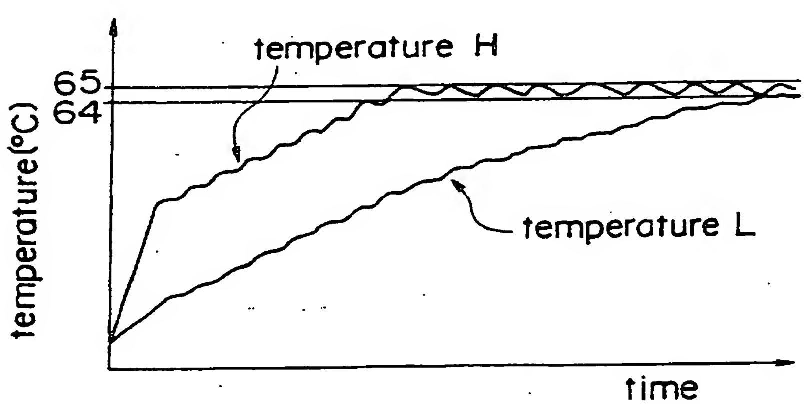


Fig.11a

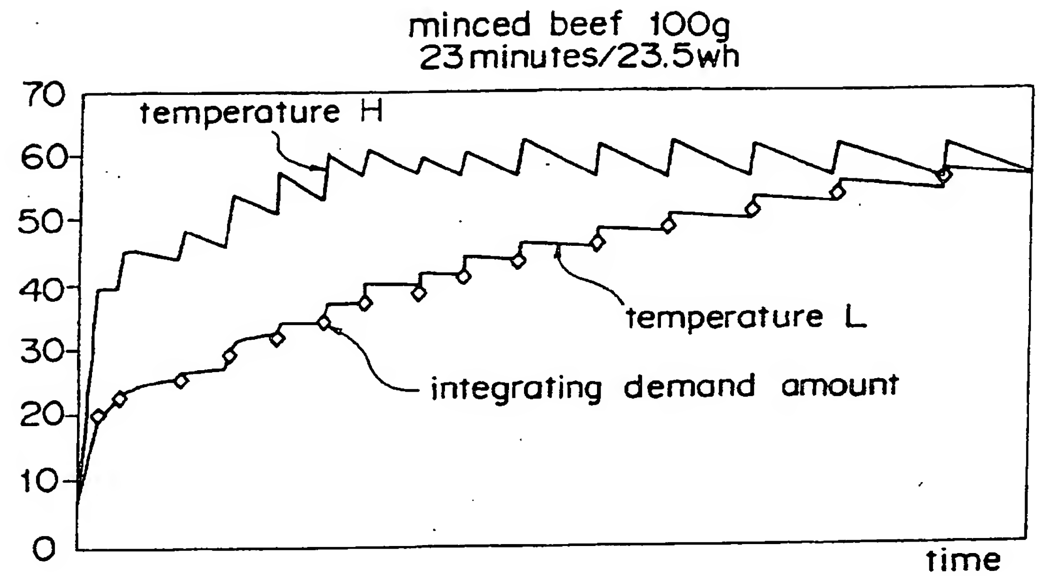


Fig.11b

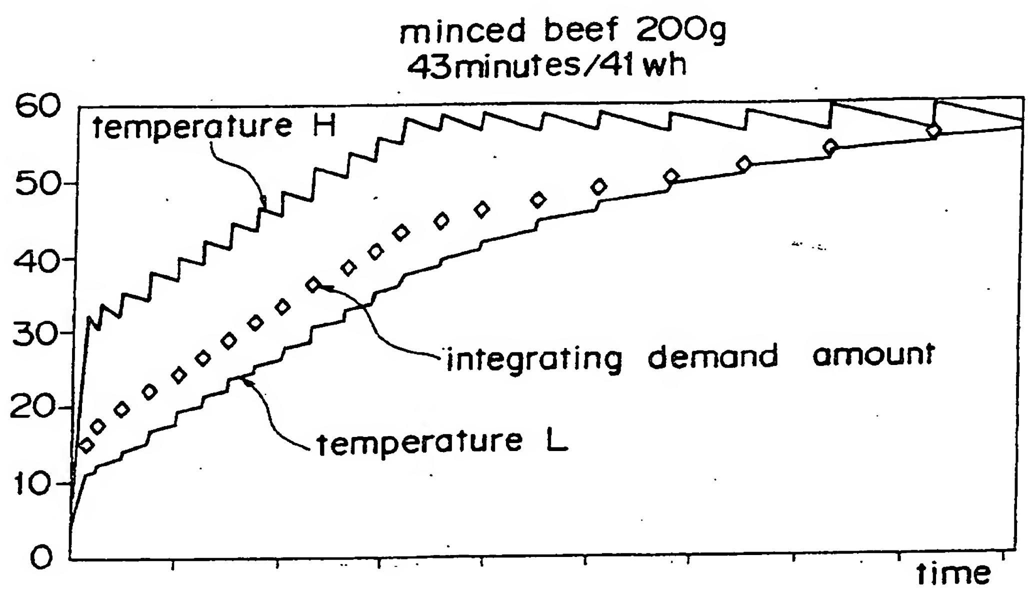


Fig.11c

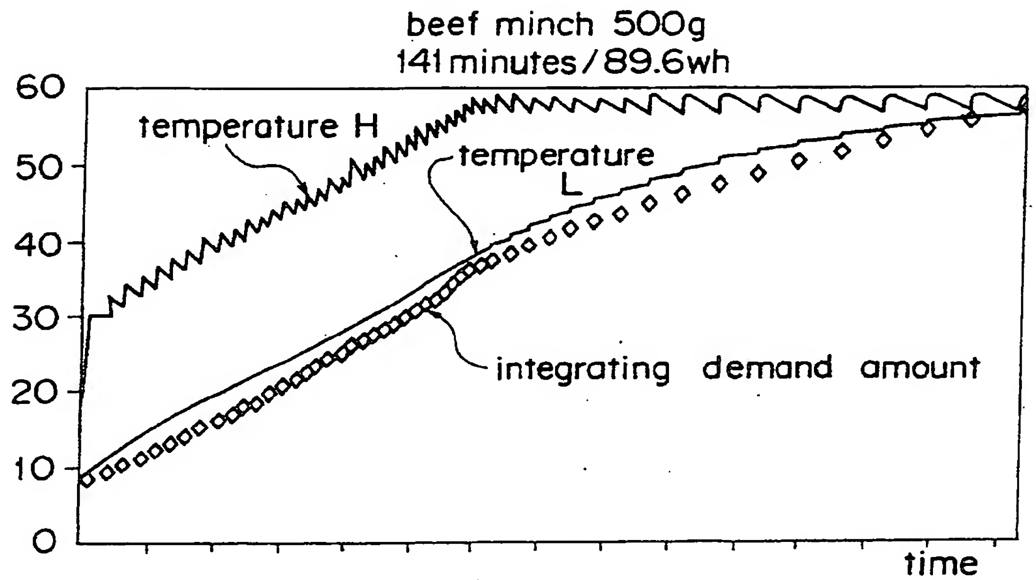


Fig.11d

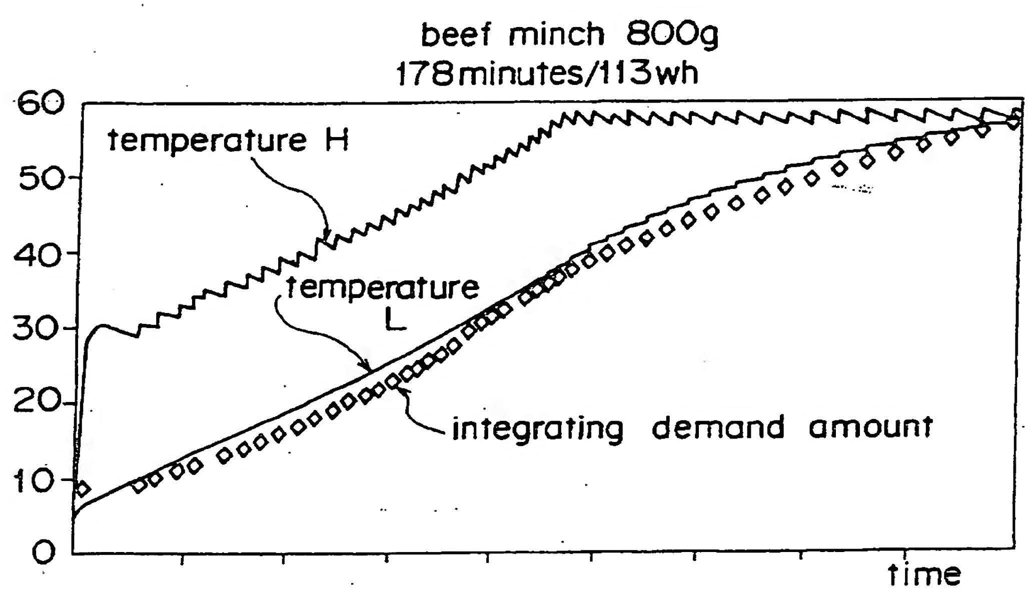


Fig.12

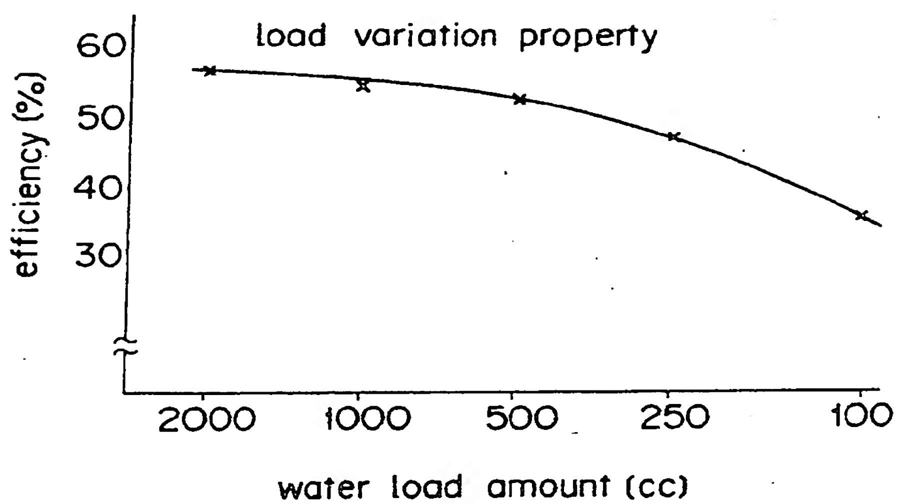

load variation property
efficiency (%)
60
50
40
30
2000
1000
500
250
100
water load amount (cc)

Fig.13

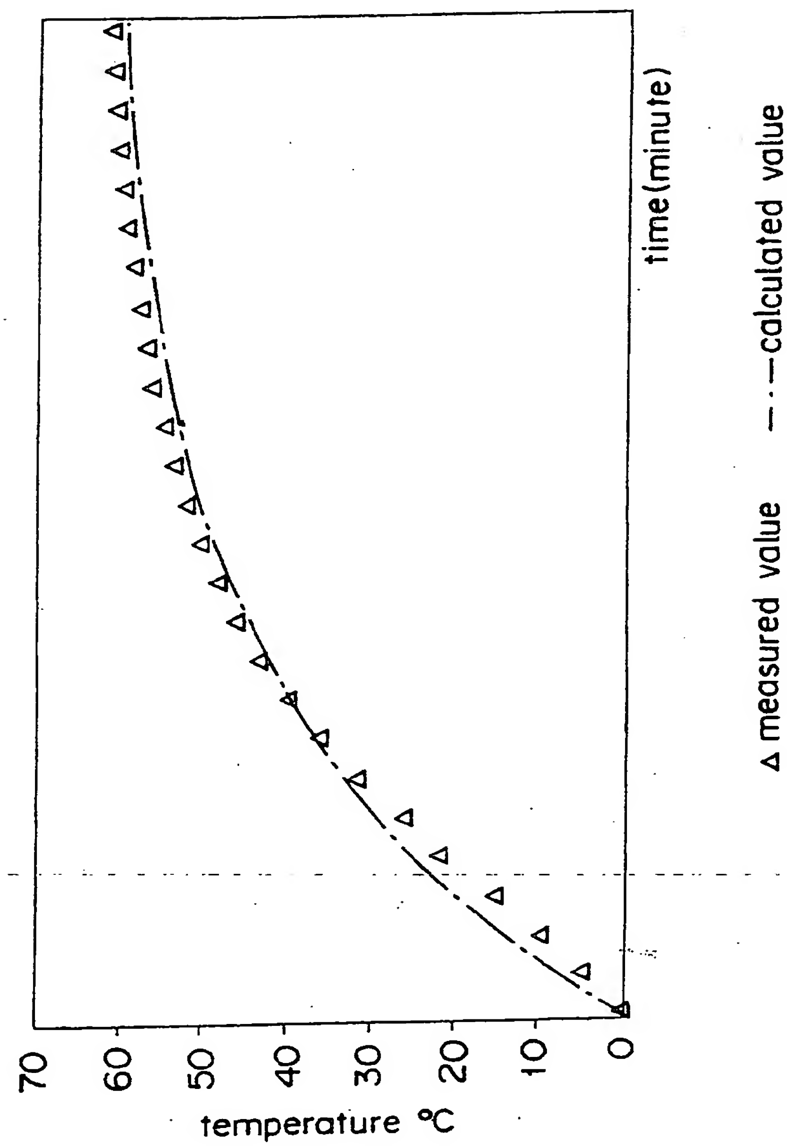

temperature ℃
70
60
50
40
30
20
10
0
time (minute)
Δ measured value
—·—calculated value

Fig.14

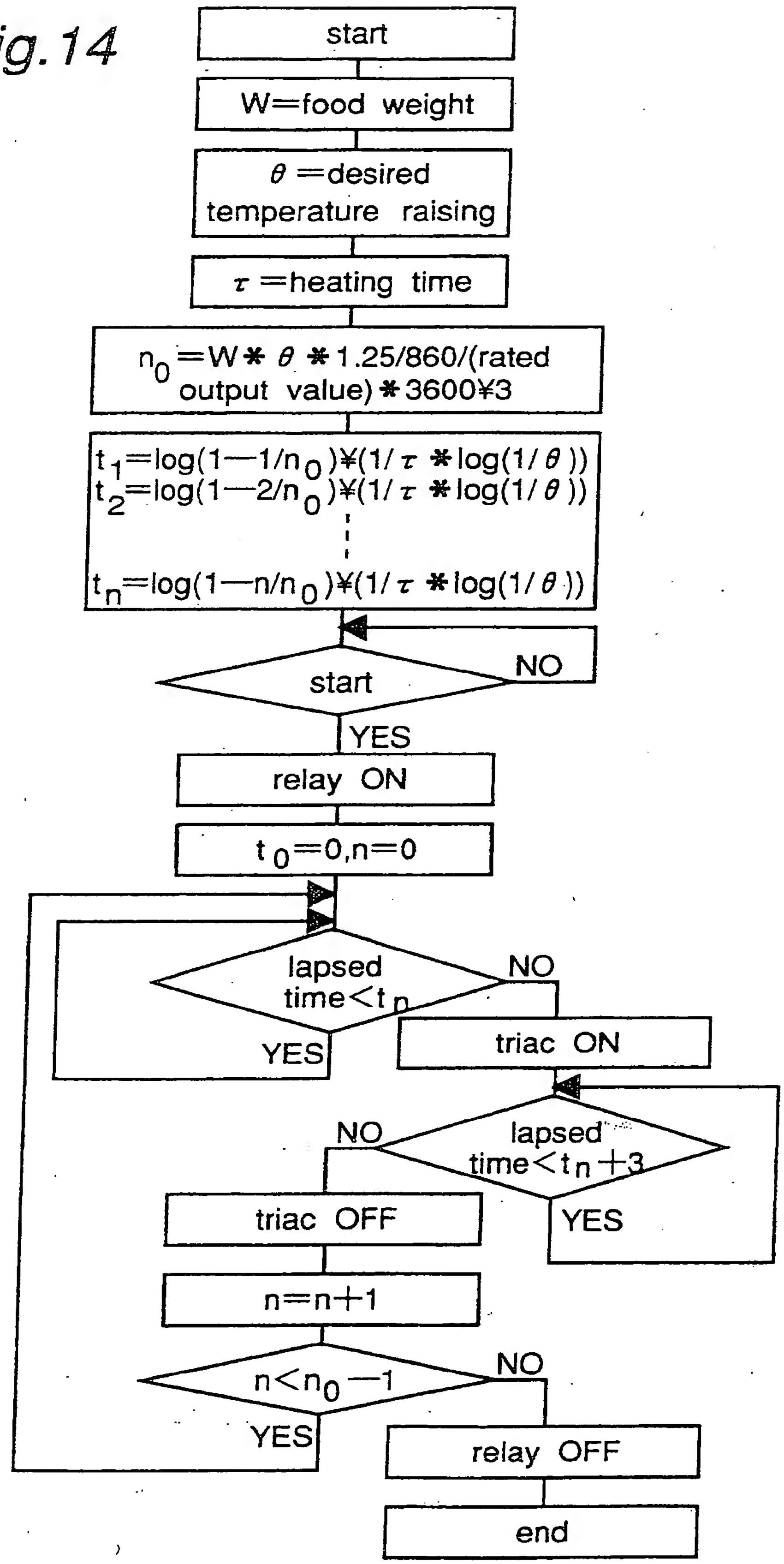

start
W=food weight
θ=desired temperature raising
τ=heating time
n0=W*θ*1.25/860/(rated output value)*3600¥3
t1=log(1−1/n0)¥(1/τ*log(1/θ))
t2=log(1−2/n0)¥(1/τ*log(1/θ))
tn=log(1−n/n0)¥(1/τ*log(1/θ))
start
NO
YES
relay ON
t0=0,n=0
lapsed time<tn
NO
YES
triac ON
lapsed time<tn+3
NO
YES
triac OFF
n=n+1
n<n0−1
NO
YES
relay OFF
end

Fig. 15

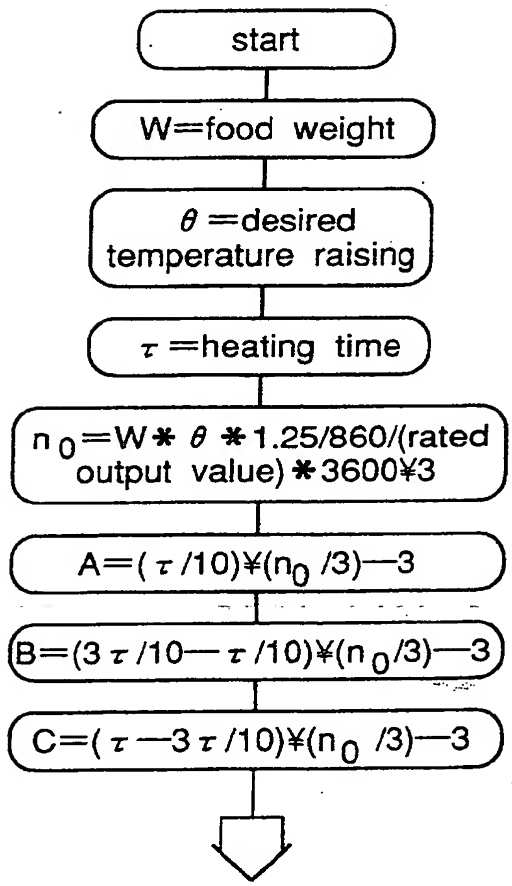
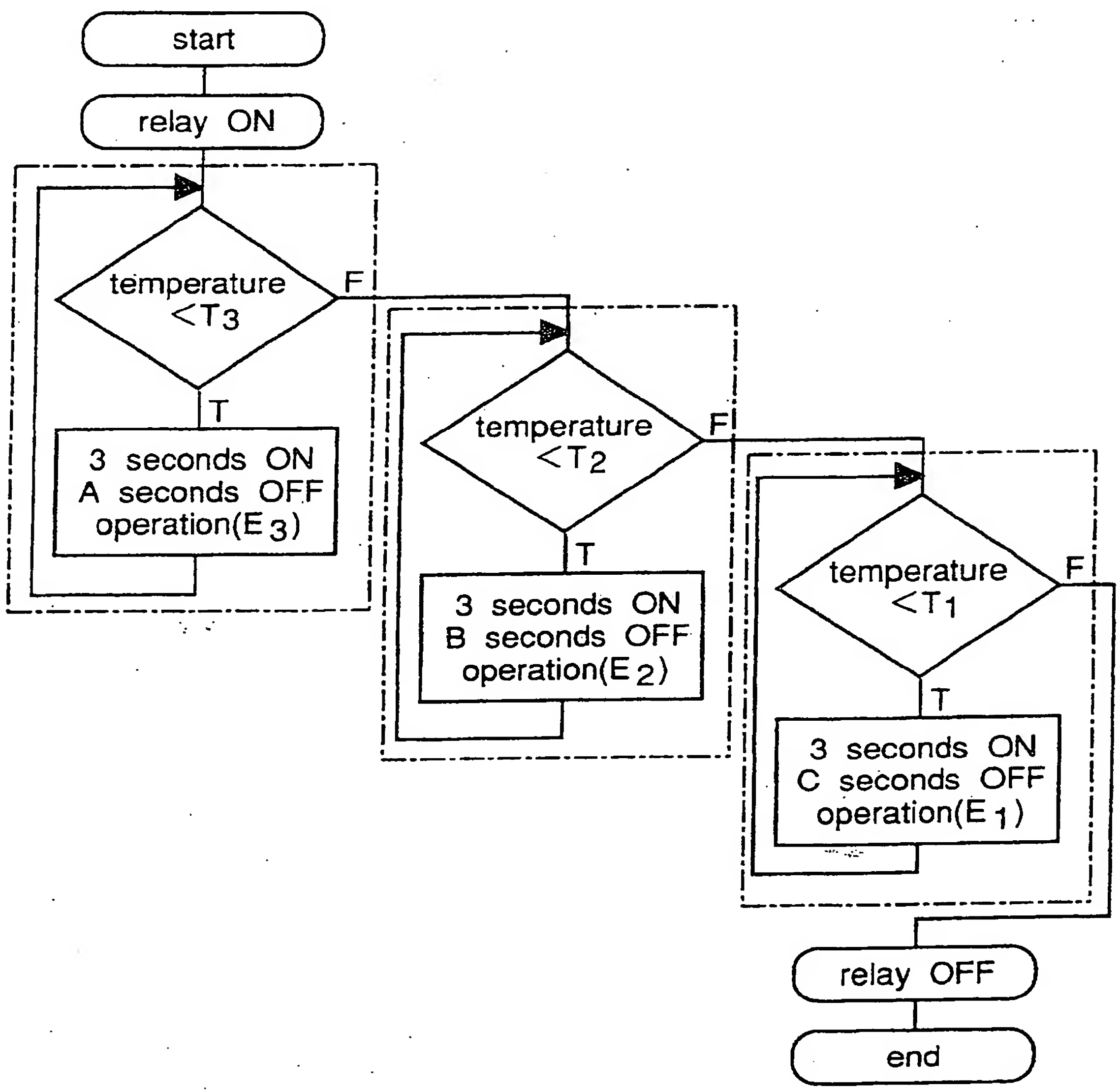

start
W=food weight
θ =desired temperature raising
τ =heating time
n_0=W* θ *1.25/860/(rated output value)*3600¥3
A=(τ /10)¥(n_0 /3)—3
B=(3 τ /10— τ /10)¥(n_0/3)—3
C=(τ —3 τ /10)¥(n_0 /3)—3

Fig.16


start
relay ON
temperature <T3
F
T
3 seconds ON
A seconds OFF
operation(E 3)
temperature <T2
F
T
3 seconds ON
B seconds OFF
operation(E 2)
temperature <T1
F
T
3 seconds ON
C seconds OFF
operation(E 1)
relay OFF
end

European Patent Office

EUROPEAN SEARCH REPORT

Application Number

EP 93120410.1

DOCUMENTS CONSIDERED TO BE RELEVANT			
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int. Cl.5)
A	PATENT ABSTRACTS OF JAPAN, unexamined applications, M field, vol. 7, no. 199, September 03, 1983 THE PATENT OFFICE JAPANESE GOVERNMENT page 117 M 240; & JP-A-58-99 623 (MATSUSHITA) --	1-4,7, 10	F 24 ~~C 7~~/08 H 05 B 6/68
A	PATENT ABSTRACTS OF JAPAN, unexamined applications, M field, vol. 12, no. 302, August 17, 1988 THE PATENT OFFICE JAPANESE GOVERNMENT page 12 M 732; & JP-A-63-75 419 (MATSUSHITA) --	1-4,7, 10	
A	PATENT ABSTRACTS OF JAPAN, unexamined applications, M field, vol. 7, no. 179, August 09, 1983 THE PATENT OFFICE JAPANESE GOVERNMENT page 148 M 234; & JP-A-58-83 132 (MATSUSHITA) ----	1-4,7, 10	TECHNICAL FIELDS SEARCHED (Int. Cl.5) F 24 C 7/00 H 05 B 6/00

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
VIENNA	09-05-1994	TSILIDIS

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
Y : particularly relevant if combined with another document of the same category
A : technological background
O : non-written disclosure
P : intermediate document

T : theory or principle underlying the invention
E : earlier patent document, but published on, or after the filing date
D : document cited in the application
L : document cited for other reasons

& : member of the same patent family, corresponding document